Volume 33 JANUARY, 1959 Number 1

PALEONTOLOGY
THE UNIVERSITY OF MICHIGAN
QE 701 .J8
FEB 10 1959
MUSEUMS LIBRARY

JOURNAL OF PALEONTOLOGY

A publication of The Society of Economic Paleontologists and Mineralogists *and* The Paleontological Society *with the generous support and cooperation of* The American Association of Petroleum Geologists *and* The Geological Society of America

CONTENTS

Mineralogy of some Foraminifera as related to their classification and ecology ..... *Paul D. Blackmon and Ruth Todd* 1
Early Devonian Ambocoeliinae (Brachiopoda) ..... *Arthur J. Boucot* 16
A new family and genus of Silurian orthotetacid brachiopods ..... *Arthur J. Boucot* 25
Some new species of Miocene Molluscs from Maryland ..... *John Oleksyshyn* 29
Scolecodonts from central Missouri ..... *Robert K. Sylvester* 33
The gasteropod genera *Liomphalus* Chapman and *Scalaetrochus* Etheridge ..... *G. M. Philip and J. A. Talent* 50
Ordovician and Silurian Cyrtogomphoceratidae (Nautiloidea) from the Oslo region, Norway ..... *Walter C. Sweet* 55
Archaeocyatha from the Colville and Salmo areas of Washington and British Columbia ..... *Robert G. Gregg* 63
A new occurrence of Devonian Radiolaria in calcareous concretions of the Huron member of the Ohio shale ..... *Helen P. Foreman* 76
On the identity of the Devonian rugose coral genus *Diversophyllum* with *Tabulophyllum*, and notes on the genus *Charactophyllum* ..... *J. Lloyd Watkins* 81
A paleoecologic and biometric study of the Middle Cambrian trilobite *Elrathia kingi* (Meek) ..... *Robert C. Bright* 83
Bayhaitsia merriamorum, a new Permian tabulate coral from California ..... *R. L. Langenheim, Jr. and V. A. McCutcheon* 99
New ammonites from the Albian of northern California ..... *Michael A. Murphy and Peter U. Rodda* 103
Trilobites from the Peerless and Manitou formations, Colorado ..... *Robert R. Berg and Reuben James Ross, Jr.* 106
Some paleobotanical problematica ..... *Roland W. Brown* 120
A bat and some plants from the upper Oligocene of Oregon ..... *Roland W. Brown* 125
Lower Mississippian holothurian sclerites from the Rockford limestone of northern Indiana ..... *Raymond C. Gutschick* 130
Devonian tetracorals from South Devonshire, England ..... *Gerard V. Middleton* 138
Actoplous vorax, a new and unusual labyrinthodont amphibian from the Kansas Permian ..... *Nicholas Hotton III* 161
New genera of Early Cretaceous (Albian) ammonites from Alaska ..... *Ralph W. Imlay* 179
Gametangial constants of extant Charophyta for use in micropaleobotany ..... *R. D. Wood* 186
CORRECTIONS 194
PALEONTOLOGICAL NOTES 195
NOTICES 199
SOCIETY RECORDS AND ACTIVITIES 202

EDITORS

For The Paleontological Society: ERWIN C. STUMM, Museum of Paleontology, University of Michigan, Ann Arbor, Michigan.

For The Society of Economic Paleontologists and Mineralogists: M. L. THOMPSON and CHARLES W. COLLINSON, Illinois State Geological Survey, Urbana, Illinois.

The JOURNAL OF PALEONTOLOGY is published bimonthly. The issues for January, May, and September are sponsored by The Paleontological Society in cooperation with The Geological Society of America; those for March, July, and November are sponsored by The Society of Economic Paleontologists and Mineralogists in cooperation with The American Association of Petroleum Geologists.

The subscription price for the JOURNAL is $15.00 per year prepaid to addresses in the United States. Postage is charged extra for all other countries in the Postal Union, 40 cents on annual subscriptions (total $15.40). Single numbers $3.00 each to nonmembers, $1.75 to members.

Communications about the JOURNAL, advertising, subscriptions, rates, change of address, and nonreceipt of preceding numbers, should be addressed to The Society of Economic Paleontologists and Mineralogists, P. O. Box 979, Tulsa 1, Oklahoma. Claims for nonreceipt of preceding numbers must be submitted within three months of the date of publication in order to be filled gratis. Communications about membership and requests for blanks for nomination of new members should be directed to the secretary of the respective society.

Communications in regard to manuscripts or purely editorial matters should be sent to the editors at addresses above.

Authors should consult a recent issue of the JOURNAL for appropriate style and form before preparing their manuscripts. A brief, informative abstract should accompany every article except nomenclatural notes only one or two paragraphs long in which the title is sufficient to serve as an abstract of the contents. All new taxonomic names proposed in a paper should appear in the abstract.

Contributors are requested to instruct their photographers to illuminate fossils from the upper left side, the conventional manner. Plates normally should be arranged for publication at the maximum size of 5¼×8½ inches, exclusive of margins and heading. Printed numerals of standard size and form may be obtained free from the editors. When requesting them state number of plates and dimensions of each plate. Text-figures should be designed for reproduction at either single column (2½ inches) or full page (5¼ inches) width, maximum height 7½ inches. Typewritten copy is not acceptable for text-figures.

OFFICERS OF THE SOCIETIES

THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

For the year ending March 1959

President

GORDON RITTENHOUSE, Houston, Texas

Past-President

R. V. HOLLINGSWORTH, Midland, Texas

Vice-President

WILLIAM M. FURNISH, Iowa City, Iowa

Secretary-Treasurer

RAYMOND E. PECK, Columbia, Missouri

Editors

M. L. THOMPSON AND CHARLES W. COLLINSON
Urbana, Illinois
for Paleontology

JACK L. HOUGH, Urbana, Illinois
for Mineralogy

THE PALEONTOLOGICAL SOCIETY

For the year ending November 1959

President

FRANK M. SWARTZ, University Park, Pa.

Vice-President

WILLIAM R. EVITT, Tulsa, Oklahoma

Secretary

HARRY B. WHITTINGTON, Cambridge, Mass.

Treasurer

CLAUDE C. ALBRITTON, Dallas, Texas

Editors

ERWIN C. STUMM, Ann Arbor, Mich.
ROBERT V. KESLING, Ann Arbor, Mich.

Past-Presidents

ARTHUR K. MILLER, Iowa City, Iowa
G. ARTHUR COOPER, Washington, D. C.
HENRYK B. STENZEL, Houston, Texas

Second-class postage paid at the Post Office at MENASHA, WISCONSIN, and at additional mailing office, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in paragraph 4, section 538, P. L. and R, authorized April 3, 1935.

Printed in U. S. A.

GEORGE BANTA COMPANY, INC., MENASHA, WISCONSIN

JOURNAL OF PALEONTOLOGY

A publication of THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS *and* THE PALEONTOLOGICAL SOCIETY *with the generous support and cooperation of* THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS *and* THE GEOLOGICAL SOCIETY OF AMERICA

VOLUME 33 JANUARY, 1959 NUMBER 1

MINERALOGY OF SOME FORAMINIFERA AS RELATED TO THEIR CLASSIFICATION AND ECOLOGY[1]

PAUL D. BLACKMON AND RUTH TODD
U. S. Geological Survey, Washington 25, D. C.

ABSTRACT—Evidence from previous and present studies indicates that the mineralogical nature of secreted calcareous shells of Foraminifera is principally a genetic characteristic. Mineral content is probably affected, but not determined entirely, by environmental influences. Most genera are wholly calcitic. Relatively few genera are wholly aragonitic and they probably belong to two closely related families.

X-ray diffraction studies of 131 genera, having calcareous shells, in 29 families of Recent Foraminifera have shown varying amounts of magnesium substitution for calcium in their shells. Certain of the calcitic shells are consistently characterized by low magnesium content (0–5 mol percent $MgCO_3$ [or 0–4.3 weight percent]) and others consistently characterized by high magnesium content (10 mol percent or higher $MgCO_3$ [8.6 weight percent]); relatively few fall into the intermediate group. A natural division of the genera of Foraminifera, related to magnesium content, is indicated.

With certain few exceptions, calcitic genera whose shells have high magnesium content are restricted to 12 families and those whose shells have low magnesium content are restricted to 10 other families. Two families seem to belong in an intermediate group. Shells from two families are aragonitic in nature, hence are very low (<1 percent) in magnesium content, a characteristic inherent in aragonitic-shelled organisms. Three families have both high and low magnesium shells.

That the mineralogy of the shells is not strictly a function of ecology is indicated by the occurrence of both high and low magnesium content types under identical environmental conditions. In addition certain genera with magnesium content of as high as 10 mol percent flourish under arctic conditions, where low temperatures generally result in low magnesium content in other calcareous invertebrates. However, deviations to intermediate or low magnesium content occur in a few genera in families whose other genera have high magnesium. This deviation indicates that phylogenetic position may not be the only factor determining mineral content. Some depression of magnesium substitution probably results from the low temperature of arctic or very deep tropical waters. The instances of deviation to high magnesium in genera of families whose other genera are low are interpreted as an indication that the genera concerned may be suspect as to their correct taxonomic placement.

The determination of magnesium content in individual Foraminifera may serve several purposes. First, it may be used as an aid in classification. Second, when the normal magnesium content is known for a generic or family group, it may be an aid in determining the original environmental conditions of the living organism. Third, the varying percentages of magnesium in carbonate sediments may result from the types of predominant Foraminifera present.

[1] Publication authorized by the Director, U. S. Geological Survey.

INTRODUCTION

A STUDY of the calcareous tests of Foraminifera was undertaken to determine the relationship of the mineralogical composition of their original shell walls to the natural classification of the Order Foraminifera and to the environment in which the organisms lived. Early workers have divided the shells into perforate and imperforate groups and in 1949 Wood further subdivided the perforate calcareous tests into radial and granular groups according to their microstructure under polarized light. More recently several authors (Bandy, 1954; Troelsen, 1955; Switzer & Boucot, 1955; Todd & Blackmon, 1956) have pointed out that another feature—namely, whether the calcium carbonate is in the form of calcite or aragonite—may have significance in the classification of Foraminifera. It is the purpose of this paper to discuss this mineralogic feature as another tool to aid in classification and identification of the organisms.

Lowenstam (1954*a*, 1954*b*) has shown that calcite and aragonite coexist in the shell structure of certain polychaetes and some mollusk genera. The temperature of their environment appears to influence directly the calcite-aragonite ratio in the shells. As the temperature increases, the proportion of aragonite to calcite increases. The shells of organisms in cold water environments would therefore tend to be mainly calcitic and shells of those in warm waters would tend to be mainly aragonitic. Shells having variable calcite-aragonite ratios would be expected in waters that have a wide temperature range over a year's time.

However, Lowenstam has also shown (1954*a*, p. 46) that phyla, orders, or even genera do not all secrete shell material at the same rate or at the same temperature threshold throughout the temperature range of oceanic waters. Therefore in a single environment where the temperature changes over a wide range annually some organisms may secrete shell only when the waters are warm. This temperature control over shell secretion may produce wholly aragonitic skeletons or shells with higher percentages of aragonite than in shells of other organisms which secrete shell at both high and low temperature. Conversely calcite may predominate when organisms secrete shell only at low temperatures or throughout the full temperature range of the ocean waters. In other words, temperature alone does not fix the aragonite to calcite ratios in the shells. This implies phylogenetic control in conjunction with a temperature effect on the shell mineralogy. We have found that the concept of temperature effect as related to calcite-aragonite content does not seem to apply to Foraminifera. The phylogenetic relationships of the organisms seem to be the major control in determining their crystal form.

We gratefully acknowledge the helpful advice and cooperation received from several colleagues, chiefly George Switzer and J. C. Troelsen, in connection with our study.

LABORATORY METHODS AND RESULTS

Studies were made of 131 genera in 29 families of Recent Foraminifera having calcareous shells. Approximately 155 species giving worldwide coverage were examined. At first consideration 131 Recent genera appear to represent a very small proportion of the known Foraminifera. On the contrary, we believe that the genera analysed include 75 to 90 percent of specimens known from Recent faunas and possibly a considerable proportion of the fossil faunas.

Our selection is based largely, but not exclusively, on the Cushman classification (Cushman, 1948). Nearly half of the 751 genera included there are removed from our consideration because no Recent species of them are known. About one-fifth more must be omitted because their shells are agglutinated. Remaining are 239 Recent calcareous genera, from which we picked 131 genera which best represented their families.

In order that the results of this study might be as widely applicable as possible, the selection of genera to be examined has been influenced by the following considerations: (1) only genera represented by Recent specimens or specimens from unindurated deepsea cores are included to avoid invalidation of results through possibility of inversion of aragonite to calcite or removal of magnesium by leaching action; (2) genera

that include many species and that are most widely distributed geographically and ecologically are included in preference to genera whose species are rare or have restricted occurrences; (3) two or more species of the same genus (or specimens of the same species) from different localities or environments are included to provide evidence relating to environmental effects; (4) most genera are represented by well-known, easily recognizable species.

Except in the few instances where numerous specimens were ground up for determination by the diffractometer-goniometer method, the individual specimens used in our study are to be found in the U. S. National Museum Collection of Foraminifera.

The mineralogy of the individual foraminifer shells was determined by X-ray diffraction using a 114.6 mm. diameter Debye-Scherrer camera as described by Todd & Blackmon (1956). Front and back reflection lines were measured in order to determine film shrinkage and facilitate accurate measurement of the line spacings. Some of the shells were much larger than the optimum 0.1 mm. diameter desired for powder X-ray analysis. As a result the diffraction lines were wide and accurate measurement was difficult. When this occurred the shell was broken and a diffraction pattern was made of a fragment of it. Diffraction lines were finer as a result of the reduction in diameter of the specimen and accurate measurement of the *d* spacings was again possible. The mineralogy of the shell was then determined from the positions of the diffraction lines.

In table 1 are included the results of our examinations.

Species and their mineralogical composition are grouped in families, the imperforate families first. For each specimen is also included its probable living habit, whether benthonic or planktonic, and the location, including depth if known, and approximate water temperature at which it lived. Descriptions and records of most of these species are found in the publications listed in the References. The arrangement of families is somewhat altered from that of the Cushman classification in favor of mineralogical and microstructural groupings.

Without exception nonagglutinated calcareous Foraminifera shells are composed of either calcite or aragonite but not a mixture of the two. Certain genera were found to be wholly aragonitic whether the shell came from an arctic or a tropical environment. Similarly certain other genera were always calcitic regardless of their habitat. In addition, both calcitic and aragonitic genera were found in the same environment. Apparently no ecological condition directly influences the deposition of either calcite or aragonite in the foraminifer shell but rather a phylogenetic control is responsible.

Only 6 of the genera analysed fall into the aragonite group. Previous work of Bandy (1954) and Troelsen (1955) adds 8 additional genera (4 Recent and 4 fossil) to this group. Inasmuch as, with two exceptions, the aragonite genera all fall into two perforate families, Robertinidae Hofker 1951 and Ceratobuliminidae Glaessner 1937 (emended Troelsen, 1954), and no calcite genera are known in these families, it has been concluded, as proposed by Troelsen (1955), that aragonite composition of test wall is a family characteristic. The two exceptions to the above statement are the Recent genus *Ungulatella* Cushman and the Upper Cretaceous genus *Colomia* Cushman & Bermudez. These genera are reported (Cushman, 1948, p. 265) to be closely related and their placement in the family Buliminidae questioned. Future studies of these and possibly other genera may result in their being grouped with the several genera that were split off from the Buliminidae and Cassidulinidae, on grounds other than type of wall, to form the family Robertinidae.

In connection with these exceptions there are several other exceptions reported from the Jurassic, namely the genus *Trocholina* which has been reported (Reichel, 1956, p. 400) to have probably been originally aragonitic, and two species placed in *Bolivina*, *B. liassica* (Terquem) and *B. rhumbleri* Franke, which are reported to be aragonitic. As aragonitic species among fossil Foraminifera are subject to alteration to calcite, it is probable that other aragonitic forms may have existed. Their discovery may alter the family and generic relationships as based on Recent Foraminifera.

TABLE 1.—SUMMARY OF RESULTS OF X-RAY ANALYSES

Calcitic species (* Indicates type species)	Probable living habit P=planktonic B=benthonic	Locality and depth of water	Approximate water temperature (°C.)	Magnesium content (mol %)
MILIOLIDAE				
Quinqueloculina sulcata d'Orbigny	B	Saipan lagoon, sta. A3	26–28	13
Q. lamarckiana d'Orbigny	B	Great Bahama Bank, mid bank, C3, 16 feet	20–30	12–16
**Q. seminulum* (Linné)	B	Off Clavering Island, near glacier, NE Greenland	0	10
Triloculina trigonula (Lamarck)	B	Saipan lagoon, sta. A3	26–28	12
T. trigonula (Lamarck)	B	Bikini lagoon, sta. 37, 11 feet	28–29	13
Miliolinella australis (Parr)	B	Rongerik lagoon, sta. 3, 101 feet	28–29	13
M. australis (Parr)	B	Saipan lagoon, sta. B10	26–28	13
M. australis (Parr)	B	Off Gabo Islands, E end Bass Strait	10–13	10
M. disciformis (Macgillivray)	B	Friday Harbor, San Juan Islands, Wash.	7–13	11
M. labiosa (d'Orbigny)	B	Dry Tortugas, Fla., sta. 12, 7 fms.	24–29	14
M. labiosa (d'Orbigny)	B	Saipan lagoon, B10	26–28	14
M. labiosa (d'Orbigny)	B	Rutavu	28	14
Biloculinella eburnea (d'Orbigny)	B	Great Bahama Bank, nearshore, All, intertidal	20–30	15–18
Pyrgo murrhina (Schwager)	B	Guyot sample off Bikini, 1176 (1–2"), 720 fms.	4	6
P. denticulata (Brady)	B	Montego Bay, Jamaica, 6 fms.	26–28	14
Massilina pseudoclara Todd	B	Saipan lagoon, sta. B8	26–28	14
Planispirina striata Sidebottom = *Massilina*	B	Delos, Mediterranean Sea	13–25	14
Spiroloculina clara Cushman	B	Rongelap, outside lagoon, sta. 468, 21 ft.	28–29	15
Hauerina involuta Cushman	B	Rongerik lagoon, sta. 79, 150 ft.	28–29	17
Sigmoilina edwardsi (Schlumberger)	B	Bikini lagoon, sta. 292, 179 ft.	27–29	17
Articulina pacifica Cushman	B	Bikini lagoon, sta. 1010, 163 ft.	27–29	17
Tubinella funalis Brady	B	Dry Tortugas, Fla., sta. 38	24–29	18
OPHTHALMIDIIDAE				
**Cornuspira planorbis* Schulze	B	Saipan lagoon, sta. FX2	26–28	14, 14
Nodophthalmidium antillarum (Cushman)	B	Dry Tortugas, Fla., sta. 37-31	24–29	14
Nodobacuriella cassis (d'Orbigny)	B	Dry Tortugas, Fla., sta. 42, 18 fms.	24–29	14
**Vertebralina striata* d'Orbigny	B	Delos, Mediterranean Sea, 10–14 fms.	13–25	14
Ophthalmidium inconstans Brady	B	Philippines, *Albatross* D5259, 312 fms.	10	9
O. inconstans Brady	B	Off Jacksonville, Fla., 800 meters	8	7
**Planispirinella exigua* (Brady)	B	Levuka, Fiji, 12 fms.	27	17
**Wiesnerella auriculata* (Egger)	B	Dry Tortugas, Fla., sta. 9-31	24–29	14
**Parrina bradyi* (Millett)	B	Bikini lagoon, sta. 33, 22 ft.	28–29	17, 18
FISCHERINIDAE				
Fischerina involuta Cushman	B	Makemo lagoon, Paumotu Is.	28	11
PENEROPLIDAE				
Peneroplis proteus d'Orbigny	B	Dry Tortugas, Fla., sta. 37, 11 fms.	24–29	16
Spirolina arietina (Batsch)	B	Saipan lagoon, sta. A3	26–28	16, 17
S. arietina (Batsch)	B	Onotoa lagoon, sta. GOC-36B, 0–1 ft.	28	15, 17
Monalysidium politum Chapman	B	Onotoa lagoon, sta. GOC-29, 1–2 ft.	28	16, 16
**Archaias angulatus* (Fichtel & Moll)	B	Great Bahama Bank	20–30	16
**A. angulatus* (Fichtel & Moll)	B	Dry Tortugas, Fla., sta. 14, 12 fms.	24–29	15
Sorites marginalis (Lamarck)	B	Onotoa lagoon, sta. GOC-36B, 0–1 ft.	28	17, 17
**Marginopora vertebralis* Blainville	B	Onotoa lagoon, sta. GOC-36B, 0–1 ft.	28	16, 16
**M. vertebralis* Blainville	B	Saipan lagoon, sta. A1	26–28	18
ALVEOLINELLIDAE				
**Alveolinella quoii* (d'Orbigny)	B	Off Eagle Is., Great Barrier Reef, 50 ft.	24–28	19
**A. quoii* (d'Orbigny)	B	Off Eagle Is., Great Barrier Reef, 50 ft.	24–28	18
Neoalveolina pulchra (d'Orbigny)	B	Rongelap, outside lagoon, sta. 456, 40 ft.	27–29	20
N. pulchra (d'Orbigny)	B	Dry Tortugas, Fla., sta. 30, 2 fms.	24–29	14
SPIRILLINIDAE				
**Patellina corrugata* Williamson	B	Western Mediterranean Sea, Swedish deep-sea core 210-10, 2782 meters	4	7
Spirillina vivipara Ehrenberg var. *revertens* Rhumbler	B	Rongerik lagoon, sta. 51, 111 ft.	28–29	17
S. vivipara Ehrenberg var. *densepunctata* Cushman	B	Bikini lagoon, sta. 1055, 128 ft.	28–29	17
LAGENIDAE				
Robulus sp. B of Cushman, Todd, & Post	B	Guyot off Bikini, sta. 1174, 410 fms.	5	0
**Planularia auris* Defrance	B	Beach at Rimini, Italy	13–25	0
Dentalina mucronata Neugeboren	B	Off Cape Charles, Va., *Albatross* D2018, 788 fms.	4	0
Rectoglandulina sp. of Todd	B	Western Mediterranean Sea, Swedish deep-sea core 08-97, 2710 meters	4	0
Lagena perlucida (Montagu)	B	Port Stanley, Falklands, 1–2 meters	5–8	0
POLYMORPHINIDAE				
Guttulina spicaeformis (Roemer) var. *australis* (d'Orbigny)	B	Dry Tortugas, Fla., sta. 37, 11 fms.	24–29	3

TABLE 1.—(*Continued*)

Calcitic species (* Indicates type species)	Probable living habit P = planktonic B = benthonic	Locality and depth of water	Approximate water temperature (°C.)	Magnesium content (mol %)
Pseudopolymorphina novangliae (Cushman)	B	Off Nonamesset Is., Vineyard Sound, Mass., 6 fms.	19–22	0
Ramulina globulifera (Brady)	B	Philippines, *Albatross* D5259, 312 fms.	10	0
**Sporadogenerina proteiformis* (Flint) (See Frizzell, 1950)	B	Off Puerto Rico, 350–400 fms.	7	0
CAMERINIDAE				
Operculina ammonoides (Gronovius)	B	Off Eagle Is., Great Barrier Reef, 50 ft.	24–28	13
Heterostegina suborbicularis d'Orbigny	B	Saipan lagoon, sta. B6	26–28	12
**Cycloclypeus carpenteri* Brady	B	Bikini outer slope, dredging from 800 to 580 ft.	12–26	13
HETEROHELICIDAE				
Plectofrondicularia advena (Cushman)	B	Off eastern U. S., *Albatross* D2202, 515 fms.	4	0
**Bolivinita quadrilatera* (Schwager)	B	Paumotu Is., *Albatross* H3840, 1585 fms.	2	2
**Bolivinella folium* (Parker & Jones)	B	Saipan lagoon, sta. B8	26–28	11
**B. folium* (Parker & Jones)	B	Samoa, sta. 9, 50 fms.	24–28	10
**B. folium* (Parker & Jones)	B	Samoa, sta. 9, 50 fms.	24–28	16
BULIMINIDAE				
Buliminella milletti Cushman	B	Rongerik lagoon, sta. 80, 74 ft.	28–29	14
B. millettti Cushman	B	Off Niau, Paumotu Is.	25–27	13
**Buliminoides williamsoniana* (Brady)	B	Onotoa lagoon, sta. GOC-53, 2 ft.	28	14, 14
**B. williamsoniana* (Brady)	B	Bikini lagoon, sta. 37, 11 ft.	28–29	15
Bulimina rostrata Brady	B	Guyot off Bikini, sta. 1175, 592 fms.	4	3
Globobulimina affinis (d'Orbigny)	B	Western Mediterranean Sea, Swedish deep-sea core 06-22, 2620 meters	4	5
Virgulina mexicana Cushman	B	Western Mediterranean Sea, Swedish deep-sea core 07-99, 2315 meters	4	3
**Bolivina plicata* d'Orbigny	B	Off Panama, *Lydonia* sta. 30, 428 fms.	6	3
**B. tortuosa* Brady = *Sigmavirgulina*	B	Rongelap lagoon, sta. 111, 13 ft.	28–29	4
Uvigerina porrecta Brady	B	Bikini outer slope, sta. 815, 55 fms.	26–27	3
**Angulogerina angulosa* (Williamson)	B	Bantry Bay, SW Ireland, 37½ fms.	10–15	2
**Trifarina bradyi* Cushman	B	Bikini outer slope, sta. 818, 500 fms.	4	3
Reussella simplex (Cushman)	B	Saipan lagoon, sta. E6	26–28	4
R. simplex (Cushman)	B	Bikini lagoon, sta. 1012, 130 ft.	28–29	4
Mimosina pacifica Cushman	B	Eniwetok outer slope, sta. 119, 500 fms.	4	3
Oolina scalariformis (Williamson)	B	Off "The Poor Knights," New Zealand, 60 fms.	13	1
O. sulcata (Walker & Jacob)	B	Labrador, coll. R. A. Bartlett, 1929	0–10	3
Fissurina circularis Todd	B	Guyot off Bikini, sta. 1176 (1–2"), 720 fms.	4	3, 3
DISCORBIDAE				
Rosalina candeiana d'Orbigny	B	Great Bahama Bank	20–30	10–15
R. opima (Cushman)	B	Saipan lagoon, sta. B10	26–28	14
R. opima (Cushman)	B	Outside Rongelap lagoon, sta. 463, 32 ft.	27–29	10
**Neoconorbina terquemi* (Rzehak)	B	Off Onslow Bay, N. C., 47 meters	22	13
Discorbina baccata Heron-Allen & Earland = genus?	B	Fox Basin, Canada	0	4, 9
**Trichohyalus bartletti* (Cushman)	B	Fox Basin, Canada	0	9, 10
Pulvinulina columbiensis Cushman = genus?	B	Canoe Pass, San Juan Is., Wash.	7–13	10
ROTALIIDAE				
**Epistomaroides polystomelloides* (Parker & Jones)	B	Saipan lagoon, sta. A3	26–28	13
**Poroeponides lateralis* (Terquem)	B	Off Gay Head, Martha's Vineyard, Mass., 10–12 fms.	19–22	11
P. cribrorepandus Asano & Uchio	B	Bikini lagoon, sta. 559, 64 ft.	28–29	13
Rotorbinella rosea (d'Orbigny)	B	Havana Harbour, Cuba	25–29	14
Stomatorbina concentrica (Parker & Jones)	B	Off Guam, 570 ft.	22	20
**Paumotua terebra* (Cushman)	B	Bikini outer slope, sta. 817, 114 fms.	18–20	9
Eponides antillarum (d'Orbigny)	B	Sand Key, Fla., 72 fms.	22–25	1
Buccella inusitata Andersen	B	30 mi. off Pt. Barrow, Alaska, 37 meters	0	3
B. sp.	B	Great Bahama Bank, sta. E9a, intertidal	20–30	1
Pseudoeponides umbonatus (Reuss)	B	Guyot off Bikini, sta. 1174 (1–2"), 410 fms.	5	3
Heronallenia sp. of Cushman, Todd, & Post	B	Outside Rongelap lagoon, sta. 468, 21 ft.	28–29	3
Pulvinulina haliotidea Heron-Allen & Earland = genus?	B	Off Faroe Is., *Goldseeker* sta. 16, 128 meters	7–13	4
Pninaella nitidula (Chaster)	B	Western Mediterranean Sea, Swedish deep-sea core 205-77, 3610 meters	4	1
Cancris oblongus (Williamson)	B	Off Baltimore, SW Ireland, 26 fms.	9–15	3
Baggina indica (Cushman)	B	Philippines, *Albatross* D5178, 78 fms.	17	2
Siphonina tubulosa Cushman	B	Eniwetok lagoon, sta. 328, 24 fms.	27–29	3
**Streblus beccarii* (Linné)	B	Flamingo Ranger sta., south tip of Fla., 2–6 ft.	20–30	3, 3
Gyroidina soldanii d'Orbigny	B	Western Mediterranean Sea, Swedish deep-sea core 211-21, 1325 meters	4	3

TABLE 1.—(*Continued*)

Calcitic species (* Indicates type species)	Probable living habit P = planktonic B = benthonic	Locality and depth of water	Approximate water temperature (°C.)	Magnesium content (mol %)
PEGIDIIDAE				
**Pegidia dubia* (d'Orbigny)	B	Saipan lagoon, sta. A8	26–28	15
**P. dubia* (d'Orbigny)	B	Off Fiji, 50–60 fms.	23	15
**Rugidia corticata* (Heron-Allen & Earland)	B	Rongerik lagoon, sta. 21, 127 ft.	27–29	3, 2
**R. corticata* (Heron-Allen & Earland)	B	Rongerik lagoon, sta. 3, 101 ft.	27–29	2
AMPHISTEGINIDAE				
Amphistegina madagascariensis d'Orbigny	B	Kapingamarangi atoll, 0–25 ft.	28	7
A. madagascariensis d'Orbigny	B	Bikini, sta. 734, beach	28–29	7
**Asterigerina carinata* d'Orbigny	B	Great Bahama Bank	20–30	4, 7
**A. carinata* d'Orbigny	B	Dry Tortugas, Fla., 15 ft.	20–30	4, 4
**A. carinata* d'Orbigny	B	Dry Tortugas, Fla., sta. 22, 6 fms.	24–29	3
**A. carinata* d'Orbigny	B	Off Onslow Bay, N. C., 27 meters	23	4
Asterigerinata mamilla (Williamson)	B	Off County Cork, Ireland, 20 fms.	9–15	3
CALCARINIDAE				
**Calcarina spengleri* (Gmelin)	B	Saipan lagoon, sta. B3	26–28	17
**C. spengleri* (Gmelin)	B	Marshall Islands	28	17
C. hispida (Brady)	B	Outside Rongelap lagoon, sta. 463, 32 ft.	27–29	17
**Baculogypsina sphaerulata* (Parker & Jones)	B	Onotoa lagoon, sta. GOC-19	28	21
**B. sphaerulata* (Parker & Jones)	B	Saipan lagoon, sta. A1	26–28	>24
CYMBALOPORIDAE				
Cymbaloporetta bradyi (Cushman)	B	Saipan lagoon, sta. A3	26–28	7
Tretomphalus planus Cushman	B, P	Bikini lagoon, sta. 1010, 163 ft.	27–29	7
ELPHIDIIDAE				
Elphidium poeyanum (d'Orbigny)	B	Great Bahama Bank	20–30	2–4
E. morenoi Bermudez	B	Great Bahama Bank, nearshore, intertidal	20–30	2, 4
E. crispum (Linné)	B	Saipan lagoon, sta. A3	26–28	3, 3
**Elphidiella arctica* (Parker & Jones)	B	Fox Basin, Canada, 25–31 fms.	0	2
GLOBIGERINIDAE				
Globigerina subcretacea Lomnicki	P	Guyot off Bikini, sta. 1172, 835 fms.	27	1, 1
**Globigerinoides rubra* (d'Orbigny)	P	Off eastern U. S., *Albatross* D2097, 1917 fms.	23	2
**Globigerinella aequilateralis* (Brady)	P	Bikini outer slope, sta. 818, 500 fms.	27	1
**G. aequilateralis* (Brady)	P	Eastern Caribbean Sea, *Albatross* H47, 1482 fms.	26–28	1
** Orbulina universa* d'Orbigny	P	Guyot off Bikini, sta. 1170, 680 fms.	27	1
**Hastigerina pelagica* d'Orbigny	P	Western Mediterranean Sea, Swedish deep-sea core 210-10, 2782 meters	4	0
**Sphaeroidinella dehiscens* (Parker & Jones)	P	Eniwetok outer slope, sta. 119, 500 fms.	27	0
**Pulleniatina obliquiloculata* (Parker & Jones)	P	Guyot off Bikini, sta. 1170 (0–1″), 680 fms.	27	2
**Candeina nitida* d'Orbigny	P	Eastern Caribbean Sea, *Albatross* H47, 1482 fms.	26–28	1
GLOBOROTALIIDAE				
Globorotalia menardii (d'Orbigny)	P	Guyot off Bikini, sta. 1175 (1–2″), 592 fms.	27	1, 0
G. menardii (d'Orbigny)	P	Off eastern U. S., *Albatross* D2052, 1098 fms.	12–17	0
**G. tumida* (Brady)	P	Off eastern U. S., *Albatross* D2042, 1555 fms.	12–17	0
ANOMALINIDAE				
Anomalina flintii Cushman	B	Off western Cuba, *Albatross* D2352, 463 fms.	7	0
Discanomalina coronata (Parker & Jones)	B	Off Savannah, Ga., *Albatross* D2416, 276 fms.	12	4
**Planulina ariminensis* d'Orbigny	B	Western Mediterranean Sea, Swedish deep-sea core 07-99, 2315 meters	4	4
**Hyalinea balthica* (Gronovius)	B	Western Mediterranean Sea, Swedish deep-sea core 08-97, 2710 meters	4	1
Cibicides lobatulus (Walker & Jacob)	B	Bikini outer slope, sta. 815, 55 fms.	26–27	3, 3
C. lobatulus (Walker & Jacob)	B	Great Bahama Bank, near outer edge, 20 ft.	20–30	5
**Anomalinella rostrata* (Brady)	B	Bikini lagoon, sta. 311, 184 ft.	27–29	2, 3
**Palmerinella palmerae* Bermudez	B	Gulf of Paria, Trinidad, B.W.I., 0–2 fms.	27–29	0, 0
**Laticarinina pauperata* (Parker & Jones)	B	Caribbean Sea, off Panama, *Albatross* D2144, 896 fms.	4	5
**Cyclocibicides vermiculata* (d'Orbigny)	B	Off Tripoli	13–25	5
PLANORBULINIDAE				
Planorbulina acervalis Brady	B	Bikini lagoon, sta. 1055, 128 ft.	27–29	13
**P. mediterranensis* d'Orbigny	B	Off Fowey, Fla., 70 fms.	22–25	13
**Planorbulinella larvata* (Parker & Jones)	B	Philippines, *Albatross* D5236, 494 fms.	5	11
**Acervulina inhaerens* Schultze	B	Orkney Is., No. Sound, 44 meters	8–10	8
**A. inhaerens* Schultze	B	Onotoa lagoon, sta. 51-S-9, 3 ft.	28	12
Gypsina globula Reuss	B	Eniwetok lagoon, sta. 329, 23 fms.	27–29	15, 15

TABLE 1.—(*Continued*)

Calcitic species (* Indicates type species)	Probable living habit P = planktonic B = benthonic	Locality and depth of water	Approximate water temperature (°C.)	Magnesium content (mol %)
RUPERTIIDAE				
**Rupertia stabilis* Wallich	B	West of Ireland, 994 fms.	4–6	3
HOMOTREMIDAE				
**Homotrema rubrum* (Lamarck)	B	Eniwetok lagoon, sta. 11, beach sands	28–29	16
**H. rubrum* (Lamarck)	B	Jamaica	26–28	16
**H. rubrum* (Lamarck)	B	Great Bahama Bank, mid bank, 16 ft.	20–30	15
NONIONIDAE				
Nonionella atlantica Cushman	B	Off Onslow Bay, N. C., 30 meters	22	2
N. atlantica Cushman	B	Great Bahama Bank, near outer edge, 20 ft.	20–30	2
Nonion pacificum (Cushman)	B	Guyot off Bikini, sta. 1175 (1–2″), 592 fms.	4	4
Astrononion sp.	B	Delos, Mediterranean Sea	13–25	2
CASSIDULINIDAE				
Cassidulina minuta Cushman	B	Rongelap lagoon, sta. 111, 13 ft.	28–29	3
C. costatula Cushman	B	Guyot off Bikini, sta. 1174 (1–2″), 410 fms.	5	3
C. subglobosa Brady	B	Guyot off Bikini, sta. 1174 (1–2″), 410 fms.	5	3
C. crassa d'Orbigny	B	Off the Falklands, 137 meters	5–7	4
Epistominella tubulifera (Heron-Allen & Earland)	B	Bikini outer slope, sta. 819, 315 fms.	7	3
E. exigua (Brady)	B	Antarctic, *Scotia* sta. 417, 1410 fms.	0	0
Ehrenbergina pacifica Cushman	B	Bikini outer slope, sta. 817, 114 fms.	18–20	3
CHILOSTOMELLIDAE				
Quadrimorphina laevigata (Phleger & Parker)	B	Western Mediterranean Sea, Swedish deep-sea core 08-97, 2710 meters	4	4
Chilostomella grandis Cushman	B?	Philippines, *Albatross* D5236, 494 fms.	5	2
**Seabrookia pellucida* Brady	B	Paumotu Is., *Albatross* H3879, 1084 fms.	2	1
Pullenia salisburyi R. E. & K. C. Stewart	B	Guyot off Bikini, sta. 1174 (10–14″), 410 fms.	5	3
**Sphaeroidina bulloides* d'Orbigny	B?	Guyot off Bikini, sta. 1174 (1–2″), 410 fms.	5	2
Aragonitic species (* indicates type species)				
ROBERTINIDAE				
Alliatina translucens (Cushman)	B	Eniwetok lagoon, sta. 325, 27 fms.	27–29	
**Robertina arctica* d'Orbigny	B	Between Shannon Is. and Hochstetter Foreland, NE Greenland	0	
**Ungulatella pacifica* Cushman	B	Off Rangiroa	27–29	
CERATOBULIMINIDAE				
**Höglundina elegans* (d'Orbigny)	B	Guyot off Bikini, sta. 1170 (0–1″), 680 fms.	4	
**H. elegans* (d'Orbigny)	B	Western Mediterranean Sea, Swedish deep-sea core 211-21, 1325 meters	4	
**H. elegans* (d'Orbigny)	B	Off Tampa, Fla., 100 fms.	12	
Lamarckina ventricosa (Brady)	B	Philippines, *Albatross* D5178, 78 fms.	17	
Ceratobulimina pacifica Cushman & Harris (Holotype)	B	Philippines, *Albatross* D5236, 494 fms.	5	

Investigation of the mineralogy of the Foraminifera shells included a study of trace element relationships. The specimens used in determining the gross mineralogy of the various genera were also used for the magnesium content analyses, as shown in table 1.

Recent works by Chave (1952, 1954) and by Goldsmith and others (1955) have shown that a direct relationship exists between the position of the strongest line (interplanar spacing 3.035 angstroms) in the calcite X-ray diffraction pattern and the mol percentage of Mg substitution for calcium in the calcite structure. The amount of displacement of the line from its normal position in the pattern increases with an increase in percentage of Mg in solid solution. The interplanar spacing represented by the line ranges between 2.970 angstroms and the normal 3.035 angstroms, the approximate range over which Goldsmith and others (1955) found naturally occurring magnesian calcites. This change in spacing occurs because of the smaller unit cell which results upon substitution of Mg for Ca in the calcite structure. The maximum variation found of 0.065 angstroms represents approximately 25 mol percent $MgCO_3$ (Goldsmith and others, 1955). This means a

change of approximately 0.0026 angstroms per mol percent of $MgCO_3$. This method was used to determine the Mg content of the calcite in the Foraminifera shells studied.

The replacement of Ca by manganese or iron will also shift the *d* spacing of the X-ray pattern. However, except under very unusual conditions the Mn or Fe content of the shells is so low that these elements make very little difference in the line position. Chemical analyses of several of the Foraminifera shells which were X-rayed confirmed the percentages of Mg indicated by the line displacement. In addition, spectrographic, X-ray and chemical analyses made by others (Emiliani, 1955, p. 379; Goldsmith and others, 1955, p. 221–222) of natural calcites and shell material indicate very little Mn or Fe substitution in most of their samples. The correction necessary to compensate for the presence of Mn or Fe is so small that it would probably fall within the limits of experimental error.

Chave (1954) has suggested that three major factors influence the Mg content of secreted calcareous shells. The gross mineralogy of the specimen, that is whether calcitic or aragonitic, is the most important. Aragonitic forms seldom contain more than 1 mol percent Mg in solid solution whereas calcitic forms often contain as much as 20 to 25 mol percent of Mg. Secondly, the complexity of the organism tends to determine the total amount of Mg in the skeletons; Mg decreasing with an increase in phylogenetic level. The range of Mg content, however, is also dependent upon the third factor—water temperature. As the temperature of the environment increases, the total Mg in the shell tends to increase. Salinity and depth of water, as well as age or size of the individual specimen, were mentioned as possibly influential, but only in a secondary capacity. Chave analysed 23 Foraminifera as well as numerous specimens from other phyla for Mg content. An appar-

TABLE 2.—MAGNESIUM CONTENT OF FORAMINIFERA FROM THE GREAT BAHAMA BANK WEST OF ANDROS ISLAND

[D = diffractometer-goniometer—many specimens ground up and combined; I = Debye-Scherrer camera—individual, uncrushed specimen.]

Species	Number of specimens	Mol % $MgCO_3$	Method of analysis
ELPHIDIIDAE			
Elphidium poeyanum	21	2–5	I
E. morenoi	2	2, 4	I
mixture of Elphidiidae	15	2–4	D
ROTALIIDAE			
Buccella sp.	1	1	I
NONIONIDAE			
Nonionella atlantica	1	2	I
ANOMALINIDAE			
Cibicides lobatulus	1	5	I
AMPHISTEGINIDAE			
Asterigerina carinata	1	4	I
DISCORBIDAE			
Rosalina candeiana	14	12–15	I
MILIOLIDAE			
Quinqueloculina lamarckiana	16	12–16	I
mixture of Miliolidae	10	12–14	D
Biloculinella eburnea	10	15–18	D
PENEROPLIDAE			
Archaias angulatus	20	14–16	D
HOMOTREMIDAE			
Homotrema rubrum	2	15	I

ent temperature effect was observed.

Emiliani (1955, p. 379) examined 20 specimens of pelagic foraminiferal shells belonging to 9 genera. X-ray and spectrographic analyses indicated less than 1 percent $MgCO_3$ in each of the shells regardless of geographic location. All of the shells came from deep ocean cores (equatorial and north Atlantic, Pacific Ocean, Caribbean Sea) where water temperatures are relatively low at the ocean floor. However, these species were floating organisms in life, hence lived and secreted their shells in relatively warm surface waters. The low Mg content is not consistent with Chave's observations on temperature influence.

In order to evaluate the relationship of temperature to Mg content of Foraminifera, an investigation was made of the Mg variation in individual specimens and in species from different families taken from a large area of fairly uniform environment. The Great Bahama Bank west of Andros Island provided the proper conditions; over 5000 square miles of shallow waters (less than 4 fathoms) with an annual temperature range of 21° to 30°C. Approximately 125 specimens were analysed by X-ray diffraction. The results are shown in table 2.

Various species of the families Elphidiidae, Rotaliidae, Nonionidae, Anomalinidae, and Amphisteginidae all contain 5 mol percent or less $MgCO_3$ in their shells. On the other hand, specimens from the families Discorbidae, Miliolidae, Peneroplidae, and Homotremidae which lived in exactly the same environment all contained more than 12 mol percent $MgCO_3$.

In general, two ranges of Mg substitution for Ca in Foraminifera are indicated; 0 to 5 mol percent and greater than 10 mol percent. In some instances 10 to 20 individual shells from each of several species were analysed. Magnesium contents varied over a range of 4 mol percent for both high and low range individual species. No general trends within the respective ranges occurred, with either the size of the shell or its sample location.

In order to determine the effect of different types of environment on a genus the specimens listed in table 3 were analysed. Anal-

TABLE 3.—RESULTS INDICATING LACK OF ENVIRONMENTAL INFLUENCE ON MAGNESIUM CONTENT IN FOUR SELECTED GENERA

[C = Chave (1954); E = Emiliani (1955); S = Switzer & Boucot (1955); X = present study]

Species	Location	Water temperature (°C.)	Mol % $MgCO_3$	Source of analysis
ELPHIDIIDAE				
Elphidium crispum	Saipan, Mariana Is.	27–28	3	X
E. morenoi	Great Bahama Bank	21–30	2	X
E. poeyanum	Great Bahama Bank	21–30	2–5	X
E. sp.	Point Barrow, Alaska	0	.33	C
E. sp.	Mount Desert, Maine	6	4.6	C
MILIOLIDAE				
Quinqueloculina lamarckiana	Great Bahama Bank	21–30	12–16	X
Q. seminulum	NE Greenland	0	10	X
Q. sp.	Bermuda	23	11.5–14.9	C
Q. sp.	Saipan, Mariana Is.	27–28	13	S
ANOMALINIDAE				
Cibicides lobatulus	Bikini, Marshall Is.	14	3	X
C. lobatulus	Great Bahama Bank	21–30	5	X
C. sp.	Point Barrow, Alaska	0	2	C
GLOBOROTALIIDAE				
Globorotalia menardii	Bikini, Marshall Is.	27	0	X
G. menardii	North Atlantic Ocean	19–25	0	X
G. tumida	North Atlantic Ocean	19–25	0	X
G. tumida	Equatorial Atlantic	25–27	<1	E
G. tumida	Equatorial Pacific	25	.07	E

yses quoted from the literature are differentiated from those of this study by letters.

Specimens belonging in the genera *Elphidium* and *Cibicides* were taken from warm waters and cold waters in both Atlantic and Pacific Oceans with temperatures ranging from 0 to 30°C. Analyses showed that Mg content stayed within the range 0–5 mol percent. Magnesium content of the genus *Quinqueloculina* were all 10 mol percent or greater regardless of environment. All specimens of the planktonic foraminifer *Globorotalia* contained less than 1 mol percent $MgCO_3$ even though they came from widely scattered ocean areas.

The results shown in tables 2 and 3 would seem to indicate that phylogenetic relationships alone control the Mg content of the shells. However, we have found evidence that cold water environments probably do have some effect on Mg contents. Genera from normally high Mg families which live in arctic or deep tropical waters show varying degrees of depression of Mg content. For example, *Quinqueloculina seminulum* from northeast Greenland with a water temperature of 0°C. is slightly depressed from a normal of 12 to 16 down to 10 mol percent. *Pyrgo murrhina* from deep water off Bikini with a water temperature of 4°C. is depressed from the greater than 12 percent normal of the Miliolidae down to 6 mol percent. Similar examples in other families have been noted, but no fixed rate of decrease of Mg with decrease in temperature has been plotted. The rate seems to vary with the different genera; however, in every specimen from a normally high Mg family, where the water temperature ranged below about 20°C., some decrease of Mg content was observed. The converse of this temperature phenomenon is not true. Where low Mg is normal for a species or genus, high water temperatures do not tend to increase the Mg content of the shell above 5 mol percent as can be seen in table 3 with the families Elphidiidae and Anomalinidae and in table 1 with numerous other families.

In table 1 the 125 genera that are composed wholly of calcite fall into two major groups: perforate and imperforate (referring to the nature of the wall). In the Cushman classification 6 families fall into the group having an imperforate wall. Omitting the Keramosphaeridae which is represented by a single genus and very rare individuals, the remaining 5 imperforate families were included in our investigations:

Miliolidae (11 genera)
Ophthalmidiidae (8 genera)
Fischerinidae (1 genus)
Peneroplidae (6 genera)
Alveolinellidae (2 genera)

Among these 28 genera of calcareous imperforate Foraminifera we found no deviation from a wholly calcitic wall and few deviations from a high Mg content. Those genera with less than 10 mol percent Mg came from environments where the water temperature was below 15°C.

In the Cushman classification the majority of the calcareous genera as well as the majority of the calcareous families fall into the group having a perforate wall. Thus 25 families (20 families having some Recent genera and 5 families extinct) and 173 Recent genera fall into this group. Some rearrangements of this classification, such as separation of Spirillinidae and Discorbidae from Rotaliidae (Galloway, 1933, p. 81, and Glaessner, 1945, p. 145), Ceratobuliminidae from Cassidulinidae (Glaessner, 1937, p. 19–27), Robertinidae from Buliminidae (Hofker, 1951, p. 379), and Elphidiidae from Nonionidae (Loeblich & Tappan, 1953, p. 95–96), alter the details but not the over-all aspect of predominance of perforate over imperforate forms among the Recent calcareous genera.

In the present study, 22 families and 97 genera belonging in the perforate group are included. Only the family Ellipsoidinidae is not represented. In this group there is no deviation from a wholly calcitic test, but there the uniformity ends. Within this group there exist the following two types of separation:

(1) a 3-fold division between radial and granular microstructure of the test and a test composed of a single crystal or an irregular mosaic of several large crystals of calcite; and

(2) a 2-fold (or perhaps 3-fold) division between (a) little or no Mg in the calcite, (b) high amounts of Mg, and possibly (c) moderate amounts of Mg. Based on the

specimens investigated, we cannot recognize any coincidence between these two types of separation.

In the following families we have found no deviation from very low amounts of Mg in solid solution in the calcite wall:

Lagenidae (5 genera)
Polymorphinidae (4 genera)
*Nonionidae (3 genera)
Elphidiidae (2 genera)
*Cassidulinidae (3 genera)
*Chilostomellidae (5 genera)
Globigerinidae (8 genera)
Globorotaliidae (1 genus)
Rupertiidae (1 genus)
*Anomalinidae (9 genera)

In these 10 families exhibiting little or no Mg content, specimens in all except the starred ones appear to have a radial microstructure of the wall. In the starred families, some or all of the species investigated by Wood (1949) have a granular microstructure of the wall.

In the following families we have found no deviation from a relatively high percentage of Mg in solid solution:

Camerinidae (3 genera)
Discorbidae (5 genera)
Calcarinidae (2 genera)
Planorbulinidae (4 genera)
Homotremidae (1 genus)

Specimens in these 5 families appear, from Wood's (1949) work, to have a radial microstructure of the wall. Another more obvious feature characteristic of these families, with the exception of the Discorbidae, is their usually robust and thick wall, such as is common in shallow, benthonic forms.

In one of the remaining families, the Spirillinidae, that were investigated by us, the wall seems to consist of a single crystal of calcite, as had been pointed out earlier by Sollas (1921, p. 208) and Wood (1949, p. 245), and the Mg content is high.

The 6 remaining families included in our study contain apparent inconsistencies. Some of these inconsistencies remain even after verification, in most cases by examination of additional samples. We therefore believe they are indications of or clues toward a fundamental family distinction within groups of species currently having no family distinctions.

These major inconsistencies are as follows:

(a) Heterohelicidae: Three individuals of *Bolivinella folium* (Parker & Jones), two from different localities, show fairly high Mg content while species of the other two genera in this family show low Mg content. The two low Mg samples originate from cold water environments which may well be the reason for their deficiency of Mg. However, in other high Mg family groups, specimens from low temperature waters give results that, although depressed to a minor degree (see families Miliolidae and Ophthalmidiidae), do not deviate as widely as these two genera. This may indicate that some members of the family Heterohelicidae secrete high Mg shells and some secrete low Mg shells. On the other hand a reevaluation of family relationships may be in order.

(b) Buliminidae: Two individuals each of *Buliminella milletti* Cushman and *Buliminoides williamsoniana* (Brady), all from different localities, show high Mg content, whereas individuals in the remaining 12 genera investigated in this family, some from high temperatures and some from low, all show low Mg content.

(c) Rotaliidae: The generic constitution of this family seems to be much in doubt and the family almost surely includes genera which are out of place according to a natural classification. For example, Wood's observation (1949, p. 250, 251) that *Gyroidina* has a granular microstructure, in contrast to most rotaliids which have radial structure, suggests that it should be included in a family with granular structure. It therefore seems probable that a heterogeneous group of genera are combined in this family. Of the 16 genera here grouped under the Rotaliidae, 5 show high Mg and 11 show low Mg.

(d) Pegidiidae: Two genera in this family give opposite results, both verified by second determinations from different localities: *Pegidia*, a large, thick-walled form showing high Mg content, and *Rugidia*, a small and relatively thin-walled form showing little or no Mg.

(e) Amphisteginidae: Numerous specimens of *Amphistegina madagascariensis* d'Orbigny, a large, heavy walled form, all have Mg contents of 7 mol percent. This

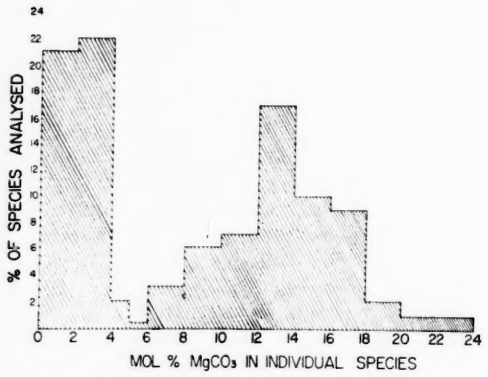
genus and the two genera examined from the family Cymbaloporidae, which also contained 7 mol percent Mg, are the only warm water (20°C. or above) genera which consistently fall in this intermediate Mg content range. In general specimens of the small and thin-walled *Asterigerina carinata* d'Orbigny contain less than 5 mol percent Mg in both warm and cool waters.

(f) Cymbaloporidae: Both genera examined in this family give results in the middle part of the range (7 mol percent of Mg), similar to the results given by the genus *Amphistegina*.

In addition to the above major deviations, there are what we regard as minor deviations probably unrelated to any fundamental family distinction. The possibility of thickness of the wall having a relationship with or an effect upon the amount of Mg in solid solution in the wall is inferred from results obtained in the families Pegidiidae and Amphisteginidae, discussed above. It is also supported by the fact that all imperforate genera, of which relatively thick walls are characteristic, have high amounts of Mg in their shells. It is further suggested by the existence of high amounts of Mg in the families Camerinidae, Calcarinidae, and Homotremidae which are also characterized by thick walls. On the other hand, however, the thick-walled form *Sphaeroidinella* shows no Mg content, and, conversely, thin-walled forms of the Planorbulinidae show high Mg content. Therefore, the evidence seems equivocal regarding any possible relationship between thickness of wall and Mg content.

Two specimens of *Discorbis baccata* from Fox Basin, Canada, 0°C., were examined, one fresh appearing, and the other whitened and opaque. The latter gave a result indicating low (4 mol percent) Mg. We believe the specimen may have been leached during a brief interval of subaerial exposure, such as temporary deposition on a beach.

There may be other factors such as maturity or size of the shell, or chemical composition of the waters which cause the minor deviations in the Mg content of similar species or genera as seen in table 1. Precise measurement of the *d* spacings is difficult and may lead to small errors. In general, it is the order of magnitude of the Mg content which is important, not the precise amount. The ranges appear to be quite distinct. The distribution of Mg content for the species analysed is shown in text figure 1. The majority of the shells fall into the ranges 0 to 5 and greater than 10 mol percent Mg. Most of those which fall in the intermediate Mg range appear to have a reduced Mg content due to the depressant effect of cold waters on normally high Mg families.



TEXT-FIG. 1—Distribution of $MgCO_3$ in Foraminifera analysed.

Again we can only speculate as to the theory of cold water effect on Mg content. This theory seems to be supported by certain specimens from the families Miliolidae, Ophthalmidiidae, Spirillinidae, Discorbidae, and Planorbulinidae. On the other hand these species may actually belong in an intermediate range group. *Amphistegina madagascariensis* and the two genera of Cymbaloporidae described earlier appear to belong in such a group. Some work on the metabolism of Foraminifera would probably help to clear up some of these problems.

CONCLUSIONS

The mineralogical determination of some 200 specimens of Foraminifera, upon which our study is based, is intended to show only trends and probabilities, and is not presumed to be conclusive for all Foraminifera, even in the instances where numerous species and genera were examined in a family. In the family Rupertiidae, for example, the

TABLE 4.—MINERALOGICAL CLASSIFICATION OF FORAMINIFERA BY FAMILIES

Imperforate	Perforate			
High magnesium calcite		Low magnesium calcite		Aragonite
	Single crystal	Radial microstructure	Granular microstructure	
Alveolinellidae Fischerinidae Miliolidae Ophthalmidiidae Peneroplidae	Spirillinidae	Calcarinidae Camerinidae Discorbidae Heterohelicidae Homotremidae Planorbulinidae Buliminidae ⟷ Buliminidae Pegidiidae ⟷ Pegidiidae Rotaliidae ⟷ Rotaliidae *Amphisteginidae *Cymbaloporidae	Anomalinidae ⟷ Anomalinidae Elphidiidae Globigerinidae Globorotaliidae Lagenidae Polymorphinidae Rupertiidae Cassidulinidae Chilostomellidae Nonionidae Rotaliidae	Ceratobuliminidae Robertinidae

* Indicates intermediate to low range.

single determination of low Mg is particularly questionable, as it might be interpreted either as depression by low temperature waters of normally high Mg or as characteristically low. Likewise, in the family Heterohelicidae, the two low Mg determinations might be interpreted as the result of low temperature instead of interpreted as a distinction within the family. Furthermore, there is no proof—only probability—that high and low Mg do not exist in specimens of the same species, genus, or even family. On the contrary, high and low Mg do exist among the genera currently placed in the families Heterohelicidae, Buliminidae, and Rotaliidae, and possibly in other families. Where this occurs we can only suggest a reexamination of family relationships. Table 4 shows a classification of the Foraminifera by families as suggested by our analyses.

An X-ray analysis of specimens of Foraminifera may serve several purposes: (a) the mineralogical nature of the wall of calcareous Foraminifera appears to be a family characteristic and thus of assistance in working out the natural classification of the Order; (b) the normal Mg content, when once determined for a family or generic group, may be an aid in determining the environmental conditions under which a particular group of specimens lived and secreted their shells; (c) the probable source of varying percentages of Mg in carbonate sediments can be determined if large numbers of Foraminifera tests are present and can be identified as to genus.

Preliminary conclusions stated in an earlier paper (Todd & Blackmon, 1956) may be amplified as follows:

(a) The gross mineralogical nature of the shell, that is whether calcitic or aragonitic, is a genetic characteristic in the Foraminifera and is not determined by environment.

(b) Among Recent Foraminifera aragonite tests seem to be restricted to the families Robertinidae and Ceratobuliminidae.

(c) No combinations of aragonite with calcite occur in the Foraminifera.

(d) Most of the genera of Foraminifera have calcitic tests, with various amounts of Mg substitution for Ca in the shell structure.

(e) Magnesium substitution in the calcitic shells of most Foraminifera falls either into a low (0–5 mol percent) range or a high (10 mol percent or higher) range with very few shells falling into an intermediate range.

(f) Magnesium content in Foraminifera shells appears to be determined by family affiliation and, in addition, affected by temperature of environment.

(g) Low temperature of environment appears to cause a minor degree of lessening of the amount of Mg substitution in the calcite shells of Foraminifera.

(h) High temperature of environment appears to have no effect in increasing amount of Mg substitution in the calcite shells of Foraminifera.

REFERENCES

The following references include works in which most of the species used for our investiga-

tions (see table 1) are recorded and illustrated, although in many instances under different generic names, and in which detailed locality data are included for most of the sample localities. References cited in the text are indicated by asterisk.

*BANDY, O. L., 1954, Aragonite tests among the Foraminifera: Jour. Sedimentary Petrology, v. 24, p. 60–61.

*CHAVE, K. E., 1952, A solid solution between calcite and dolomite: Jour. Geology, v. 60, p. 190–192.

*——, 1954, Aspects of the biogeochemistry of magnesium. 1. Calcareous marine organisms: Jour. Geology, v. 62, p. 266–283.

CLOUD, P. E., JR., 1952, Preliminary report on geology and marine environments of Onotoa Atoll, Gilbert Islands: Atoll Res. Bull. 12, Pac. Sci. Board, 73 p., 8 figs., 5 tables.

CUSHMAN, J. A., 1921, Foraminifera of the Philippine and adjacent seas: U. S. Natl. Mus. Bull. 100, v. 4, 608 p., 100 pls., 52 figs.

——, 1921, Foraminifera from the north coastt of Jamaica: U. S. Natl. Mus. Proc., v. 59, p. 47–82, pls. 11–19, figs. 1–16.

——, 1922, Shallow-water Foraminifera of the Tortugas region: Carnegie Inst. Washington Pub. 311, 85 p., 14 pls.

——, 1922–1931, The Foraminifera of the Atlantic Ocean, Parts 3–8: U. S. Natl. Mus. Bull. 104, pt. 3, 149 p., 26 pl.; pt. 4, 228 p., 42 pls.; pt. 5, 55 p., 8 pls.; pt. 6, 129 p., 22 pls.; pt. 7, 79 p., 18 pls.; pt. 8, 179 p., 26 pls.

——, 1927, Recent Foraminifera from off the west coast of America: Scripps Inst. Oceanography Bull., Tech. ser., v. 1, no. 10, p. 119–188, pls. 1–6.

——, 1932–1942, Foraminifera of the Tropical Pacific, Parts 1–3: U. S. Natl. Mus. Bull. 161, pt. 1, 88 p., 17 pls.; pt. 2, 79 p., 19 pls.; pt. 3, 67 p., 15 pls.

——, 1944, Foraminifera from the shallow water of the New England Coast: Cushman Lab. Foram. Research Special Pub. 12, 37 p., 4 pls.

——, 1947, New species and varieties of Foraminifera from off the southeastern coast of the United States: Cushman Lab. Foram. Research Contr., v. 23, p. 86–92, pls. 18–20.

——, 1948, Arctic Foraminifera: Cushman Lab. Foram. Research Special Pub. 23, 79 p., 8 pls.

*——, 1948, Foraminifera, their classification and economic use: 605 p., 4th ed., Harvard Univ. Press, Cambridge, Mass.

——, (unpublished ms., Geol. Soc. America), The occurrence of Recent Foraminifera south of Cape Hatteras and their bearing on the ecologic conditions of Tertiary faunas of the same general area.

CUSHMAN, J. A., & PARKER, F. L., 1931, Recent Foraminifera from the Atlantic coast of South America: U. S. Natl. Mus. Proc., v. 80, art 3, p. 1–24, pls. 1–4.

CUSHMAN, J. A., & TODD, RUTH, 1947, Foraminifera from the coast of Washington: Cushman Lab. Foram. Research Special Pub. 21, 23 p., 4 pls.

——, & POST, RITA, 1954, Recent Foraminifera of the Marshall Islands: U. S. Geol. Survey Prof. Paper 260-H, p. 319–384, pls. 82–93, figs. 116–118.

*EMILIANI, CESARE, 1955, Mineralogical and chemical composition of the tests of certain pelagic Foraminifera: Micropaleontology, v. 1, p. 377–380.

*FRIZZELL, D. L., 1950, The genotype and systematic position of *Sporadogenerina* Cushman (Foraminifera, Polymorphinidae): Studies honoring Trevor Kincaid, Univ. Washington Press, p. 41–43.

*GALLOWAY, J. J., 1933, A manual of Foraminifera: 483 p., 42 pls., The Principia Press, Inc., Bloomington, Ind.

*GLAESSNER, M. F., 1937, On a new family of Foraminifera: Studies in Micropaleontology, v. 1, fasc. 3, p. 19–29, pls. 1, 2.

*——, 1945, Principles of micropaleontology: 296 p., 14 pls., 64 figs., Melbourne Univ. Press, Victoria, Australia.

*GOLDSMITH, J. R., GRAF, D. L., & JOENSUU, O. I., 1955, The occurrence of magnesian calcites in nature: Geochim. et Cosmochim. Acta, v. 7, no. 5, p. 212–230.

*HOFKER, JAN, 1951, The Foraminifera of the *Siboga* Expedition, pt. III: *Siboga*-Exped., Mon. IVa, 513 p., 348 figs.

*LOEBLICH, A. R., JR., & TAPPAN, HELEN, 1953, Studies of Arctic Foraminifera: Smithsonian Misc. Coll., v. 121, no. 7, 150 p., 24 pls., 1 fig.

*LOWENSTAM, H. A., 1954*a*, Environmental relations of modification compositions of certain carbonate-secreting marine invertebrates: Natl. Acad. Sci. Proc., v. 40, p. 39–48.

*——, 1954*b*, Factors affecting the aragonite:calcite ratios in carbonate-secreting marine organisms: Jour. Geology, v. 62, p. 284–321.

PHLEGER, F. B., PARKER, F. L., & PEIRSON, J. F., 1953, North Atlantic Foraminifera: Swedish Deep-sea Exped. Repts., v. 7, no. 1, 122 p., 12 pls., 26 text figs.

*REICHEL, MANFRED, 1956, Sur une Trocholine du Valanginien d'Arzier: Ecologae Geol. Helvetiae, v. 48, no. 2, 1955 (1956), p. 396–408, pls. 14–16, figs. 1–5.

SIDEBOTTOM, HENRY, 1904–1909, Report on the Recent Foraminifera from the coast of the island of Delos (Grecian Archipelago), Parts 1–6: Manchester Lit. Philos. Soc. Mem. and Proc., v. 48, pt. 2, p. 1–26, pls. 2–5; v. 49, pt. 2, 22 p., 3 pls.; v. 50, pt. 2, 18 p., 2 pls.; v. 51, pt. 3, 28 p., 4 pls.; v. 52, pt. 3, 28 p., 5 pls.; v. 53, pt. 3, 32 p., 5 pls.

*SOLLAS, W. J., 1921, On *Saccammina carteri* Brady, and the minute structure of the foraminiferal shell: Geol. Soc. London Quart. Jour., v. 77, pt. 3, p. 193–212, figs. 1–7, pl. 7.

*SWITZER, GEORGE, & BOUCOT, A. J. 1955, The mineral composition of some microfossils: Jour. Paleontology, v. 29, p. 525–533, figs. 1–3.

TODD, RUTH, 1957, Geology of Saipan, Mariana Islands. Smaller Foraminifera: U. S. Geol.

Survey Prof. Paper 280-H, p. 265–320, pls. 2, 4, 64–72.

——, 1959, Foraminifera from western Mediterranean deep-sea cores: Swedish Deep-sea Exped. Repts., v. 8, no. 2.

*TODD, RUTH, & BLACKMON, PAUL, 1956, Calcite and aragonite in Foraminifera: Jour. Paleontology, v. 30, p. 217–219.

TODD, RUTH, & BRONNIMANN, PAUL, 1957, Recent Foraminifera and Thecamoebina from the eastern Gulf of Paria, Trinidad: Cushman Found. Foram. Research Special Pub. 3, 43 p., 12 pls., 7 figs.

*TROELSEN, J. C., 1954, Studies on Ceratobuliminidae (Foraminifera): Dansk Geol. Foren. Medd., Band 12, p. 448–477, pls. 10, 11, figs. 1–3.

*——, 1955, On the value of aragonite tests in the classification of the Rotaliidea: Cushman Found. Foram. Research Contr., v. 6, p. 50–51.

WILLIAMSON, W. C., 1858, On the Recent Foraminifera of Great Britain: Ray Soc., London, 1858, 107 p., 7 pls.

*WOOD, ALAN, 1949, The structure of the wall of the test in the Foraminifera; its value in classification: Geol. Soc. London Quart. Jour., v. 104, p. 229–255, pls. 13–15.

MANUSCRIPT RECEIVED JULY 15, 1958.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 16–24, PLS. 1–2, JANUARY 1959

EARLY DEVONIAN AMBOCOELIINAE (BRACHIOPODA)

ARTHUR J. BOUCOT
Department of Geology and Geophysics, Massachusetts Institute of Technology

ABSTRACT—The rare ambocoeliinid genus *Metaplasia* Hall & Clarke, 1893, occurs only in North America. A new ambocoeliinid genus, *Plicoplasia*, occurs in North America, South America, and South Africa. *Plicoplasia* is notable for the development of strong radial plications, a feature absent in most genera belonging to the Ambocoeliinae. *Metaplasia* is closely related to *Ambocoelia*, but the presence of a low fold and low lateral plications on the brachial valve of the former serves to distinguish the two genera. Both *Metaplasia* and *Plicoplasia* are known from strata of Siegen to Ems age (=Oriskany to Onondaga age), and could conceivably have been derived from the earliest Lower Devonian species of *Ambocoelia* described by Kozlowski (1929, p. 198–201) from Podolia. *Ambocoelia* is also known in the late Lower Devonian of Czechoslovakia and Bolivia. A spinoise, weakly plicate new ambocoeliinid genus, *Spinoplasia*, has been recognized in strata of Gedinnian (=New Scotland) age in Gaspé.

INTRODUCTION

IN connection with studies of Appalachian Early Devonian brachiopods the writer's attention was brought to strongly plicated ambocoeliinids formerly described as *Metaplasia plicata* Weller, 1903. The Appalachian specimens were observed to be generically similar to specimens from South America. Restudy of specimens belonging to Hall & Clarke's (1893, p. 56–58) genus *Metaplasia* showed that pronounced external differences exist between it and the forms here assigned to *Plicoplasia*. In North America *Plicoplasia* is known only from strata of Oriskany to Onondaga age, and the writer considers that the strata in the southern hemisphere containing this genus are also of late Lower Devonian age. The occurrence of *Plicoplasia* in the Malvinocaffric Province and in North America is another bit of evidence linking the Lower Devonian brachiopod faunas of these two regions more closely to each other than to those of western Europe and North Africa.

SYSTEMATIC DESCRIPTIONS

Superfamily SPIRIFERACEA Waagen, 1883
Family SPIRIFERIDAE King, 1846
Subfamily AMBOCOELIINAE George, 1931
Genus METAPLASIA Hall & Clarke, 1893

Type species.—*Spirifer pyxidatus* Hall, 1859, Paleontology of New York, v. 3, p. 428, pl. C, figs. 9–12.

Diagnosis.—Ambocoeliinids bearing a fold on the brachial valve flanked laterally by low, broad plications.

Comparison.—*Metaplasia* differs from post-Lower Devonian ambocoeliinids in its possession of a fold on the brachial valve flanked laterally by low plications. Externally it differs from *Plicoplasia* in lacking well-developed, angular plications.

Exterior.—The brachial valve is relatively flat; the pedicle valve is highly convex, subpyramidal in form. The hinge line is straight and about four-fifths of the maximum width, which is situated about one-third of the distance anterior of the hinge line. The lateral commissures are rectimarginate, the anterior commissure gently uniplicate and weakly crenulate. The lateral margins are gently rounded into the sharply rounded anterior margin. The shells are subcircular to laterally elongate in outline. The interarea of the brachial valve is relatively narrow, about one-fifth the length of the interarea of the pedicle valve, and its posterior margin is parallel to the hinge line. The interarea of the brachial valve is anacline, that of the pedicle valve strongly incurved, apsacline. The posterior margin of the pedicle valve's interarea makes an angle of about 15 to 45 degrees with the hinge line. The coarse ornamentation consists of a broad, low fold on the brachial valve, with a corresponding sulcus on the pedicle valve, bounded laterally by one or two pairs of broad, low interspaces lateral to which are one or two pairs of broad, low plications. The flanks of both valves are unplicated or very feebly plicated. Well developed concentric growth lines are prominent on the anterior portions

of the valves. Fine radial ornamentation or spines have not been observed. Small specimens tend to be subequally biconvex but large specimens always possess a highly convex pedicle valve and an almost flat or very gently convex brachial valve. The shell substance is impunctate.

Interior of the brachial valve.—The cardinalia consist of an elongate, simple or medially cleft, prostrate cardinal process, lateral to which are medially inclined crural plates. The crural plates are thin and triangular in form, meeting the floor of the valve on either side of the midline in some forms, but almost joining medially to form a cruralium-like structure in others. The dental sockets are simple and laterally directed. The adductor field is prominent, extending anteriorly to a point just beyond the mid-length. The adductor field consists of two pairs of impressions, a smaller, posterior elongate pair joining with an anterior, elliptical larger pair. The adductor field equals about one-quarter of the maximum width of the shell. Laterally diverging vascular trunks originating in the notothyrial region may or may not be present; if present, they radiate laterally. The interior of the valve is smooth except for the impression of the external plications, fold, and concentric growth lines.

Interior of the pedicle valve.—The pedicle valve lacks dental lamellae, but stout hinge-teeth tracks border the sides of the delthyrial cavity and serve to support the stubby hinge teeth. The teeth are situated on the medial terminations of the interarea. The delthyrium includes an angle of 45 to 60 degrees. The muscle field is deeply impressed posteriorly but becomes indistinct anteriorly. It extends anteriorly to about the midlength and is medially divided by a well defined myophragm. The muscle field bears several pairs of radial striations, but subdivisions cannot be defined. The umbonal cavities may be pitted. The interior is smooth except for the impress of the plications. The bottom of the delthyrial cavity is filled with secondary material to form an apical callosity which merges upward with the tracks of the hinge teeth.

Species assigned.—Spirifer pyxidatus Hall, 1859, op. cit. *Spirifer paucicostatus* Schuchert, 1913, Md. Geol. Survey, Silurian, p. 402, pl. 68, figs. 30–31. *Metaplasia minuta* Boucot, n. sp.

Distribution.—Strata of Oriskany and Onondaga age in eastern North America.

Metaplasia minuta Boucot, n. sp.
Pl. 2, figs. 18–24

Exterior.—The brachial valve is gently convex and the pedicle valve subpyramidal in form. The shells are laterally elongate. The lateral margins are strongly rounded and the anterior margin gently rounded. The hinge line is straight, and the greatest width is situated at about one-third of the distance anterior of the posterior margin. The anterior commissure is feebly uniplicate and crenulate. The interarea of the brachial valve is less than one-fifth as long as that of the pedicle valve. The interarea of the pedicle valve is strongly apsacline and gently incurved; that of the brachial valve is anacline. The coarse ornamentation consists of a low, rounded fold on the brachial valve bounded by two pairs of low, rounded lateral plications. The lateral plications are separated by low, rounded interspaces. Fine ornamentation has not been observed. The delthyrium includes an angle of about 40 degrees. The posterior margins of the interarea of the pedicle valve make an angle of about 60 degrees with the hinge line, but the posterior margin of the brachial valve parallels the hinge line. The shells are relatively small, never exceeding about five mm. in greatest dimension.

Interior of the brachial valve.—The cardinalia consists of a low, linear cardinal process, lateral of which are medially inclined crural plates. The crural plates are triangular in form. Pointed crura are given off from the lower, anterior faces of the crural plates. The dental sockets are simple and laterally directed. The muscle field is feebly impressed and extends about two-thirds the distance to the anterior margin. The muscle field is divided into a narrow, medial, small pair of adductor impressions bounded laterally by a larger pair of elongate adductor impressions. The interior is smooth except for the impress of the external plications.

Interior of the pedicle valve.—The delthyrial cavity is not occupied by apical callous, but is laterally bounded by the tracks of the hinge teeth. The hinge teeth are stubby and

are situated on the inner margins of the interarea, adjacent to the edges of the delthyrial cavity. The muscle field is not discernible but a low myophragm extends to about the midlength. The interior is smooth except for the impress of the external ornamentation.

Comparison.—*M. minuta* can be distinguished from both *M. pyxidata* and *M. paucicostata* by its more laterally elongate outline and by the possession of two rather than one pair of low lateral plications.

Distribution.—Upper part of the Moose River sandstone in Somerset County, Maine in strata of Onondaga age (zone of *Amphigenia*), and in the coeval Camden chert of western Tennessee (Dunbar, 1919, p. 87, *Metaplasia pyxidata* Dunbar not Hall). The writer has studied specimens from both areas in the collections of the U. S. National Museum.

Holotype.—USNM No. 126086A, B from USGS locality SD-2750 (Northeast ninth of Brassua Lake quadrangle, Somerset County, Maine. Ledges and loose blocks at end of Baker Brook Point).

Figured specimens.—USNM No. 126110.

Unfigured specimens.—USNM Nos. 126597–126600.

SPINOPLASIA Boucot, n. gen.

Type species.—*Spinoplasia gaspensis* Boucot, n. sp.

Diagnosis.—Ambocoeliinids bearing a fold on the brachial valve flanked laterally by low, broad plications, and bearing fine spines on the exterior.

Comparison.—*Spinoplasia* differs from *Metaplasia* in its possession of spinose fine ornamentation. *Spinoplasia* differs from *Plicoplasia* in the presence of spinose fine ornamentation and the absence of well-developed angular plications.

Exterior.—Both valves are similar in form to those of *Metaplasia*. The fine ornamentation consists of concentric growth lamellae bearing rows of fine spines.

Interior of the brachial valve.—The cardinalia consist of an elongate, simple, prostrate cardinal process, lateral to which are medially inclined crural plates. The crural plates are thin and triangular in form, meeting the floor of the valve on either side of the midline so as almost to form a cruralium-like structure. The dental sockets are simple and laterally directed. The adductor field is prominent, extending anteriorly to a point just beyond the mid-length. The adductor field consists of two pairs of impressions—a smaller, posterior elongate pair joining with an anterior, elliptical larger pair. The muscle field is medially bisected by a groove. The adductor field equals about one-fifth of the maximum width of the shell. The interior of the valve is smooth except for the impression of the external plications, fold, and concentric growth lines.

Interior of the pedicle valve.—The interior of the pedicle valve is similar to that of *Metaplasia*.

Species assigned.—*Spinoplasia gaspensis* Boucot, n. sp.

Distribution.—Strata of Early Devonian (Helderberg) age in southwestern Gaspé, Quebec.

Spinoplasia gaspensis Boucot, n. sp.
Pl. 2, figs. 14–16

Description.—The description of the type and only species corresponds to that given for the genus.

Distribution.—Strata of New Scotland age (upper Gedinnian equivalent) in southwestern Gaspé, Quebec. The type and only locality is Dr. Jacques Béland's Quebec Department of Mines locality No. 37, near the boundary of Nouvelle and Mann townships, one-half mile south of Escuminac River, south tip of lot 20, range Scaumenac (Escuminac) West, Nouvelle township, Bonaventure County, Quebec (66°33.5′ west, 48°08.5′ north). The enclosing strata consist of olive-drab, soft-weathering shale.

Holotype.—Peter Redpath Museum No. 2.3560A–B (a brachial valve).

Figured specimens.—Peter Redpath Museum No. 2.3561A–B (a pedicle valve).

Age of the containing strata.—Associated with *Spinoplasia gaspensis* at Béland's locality No. 37 is *Leptocoelia* sp. aff. *L. flabellites* (pl. 2, fig. 17), *Leptaena "rhomboidalis,"* and *Rhipidomelloides* sp. At the nearby locality No. 39 (one and three-quarters mile east of boundary separating Nouvelle and Mann townships and one mile south of Escuminac River, in undivided part of Nouvelle township, Bonaventure County, Quebec; 66°31.5′ west, 48°08.5′ north), *Nano-*

thyris sp. cf. *N. subglobosa* (Weller, 1903) (pl. 2, figs. 6–7), and *Skenidium* sp. (pl. 2, figs. 10–11) occurs in similar olive-drab, soft-weathering shales. The *Leptocoelia* is similar to an undescribed form occurring in strata of New Scotland age, submitted to the writer for study by Mr. Garry McG. Boone, from the Fish River Lakes quadrangle, Aroostook County, Maine. The *Nanothyris* and *Skenidium* are similar to forms found elsewhere in eastern North America in strata of New Scotland age. It is concluded that the beds containing *Spinoplasia* are of New Scotland age.

PLICOPLASIA Boucot, n. gen.

Type species.—Plicoplasia cooperi Boucot, n. sp.

Diagnosis.—The genus *Plicoplasia* is erected to include coarsely plicated, non spinose ambocoeliinids having on the pedicle valve a strongly biplicate fold and on the brachial valve a sulcus that contains a median plication of variable strength.

Comparison.—Plicoplasia differs from *Metaplasia* in the possession of strong median and lateral plications, and from all other members of the Ambocoeliinae by the possession of strong lateral plications.

Exterior.—The brachial valve is either flat or gently convex, and the pedicle valve is strongly convex to subpyramidal. The brachial valve bears a median sulcus which may be either deep or very shallow. The median sulcus may contain a relatively low, angular plication or a relatively broad, sharply defined plication. The hinge line is straight and almost equal to the maximum width which is situated about one-quarter of the distance to the anterior margin. The shells are laterally elongate and have an elliptical outline. The lateral and anterior margins are evenly rounded. The anterior commissure is strongly plicated and sulcate. The interarea of the brachial valve is about one-third to one-fifth as long as that of the pedicle valve. The brachial interarea is anacline; the pedicle interarea is apsacline and may be slightly or strongly incurved. The posterior margin of the brachial interarea is parallel to the hinge line, whereas that of the pedicle valve makes an angle of from 15 to 45 degrees with the hinge line. The delthyrium is open and includes an angle of about 30 to 45 degrees. The fine ornamentation consists of concentric growth lines. The coarse ornamentation consists of a variably developed sulcus on the brachial valve which contains a median plication and two to four strong pairs of lateral plications. The median plication is of variable size. The lateral plications are rounded or flat in cross-section and are separated by deep, U-shaped or flat bottomed interspaces.

Interior of the brachial valve.—The cardinalia consists of an elongate cardinal process which may be deeply cleft medially or deeply striated. Lateral of the cardinal process are medially inclined crural plates. The crural plates are triangular in outline and extend anteriorly beyond the cardinal process. The basal free portions of the crural plates are pointed and form the crura. The crural plates medially border the simple dental sockets, which may be basally occupied by fulcral plates. The adductor muscle field is elongate in form and extends past the midlength. The adductor field consists of an elongate posterior pair of impressions that are anteriorly bounded by an elongate anterior pair of impressions. The interior of the valve is smooth and strongly crenulated by the impress of the external ornamentation. The plications bordering the pedicle sulcus are the largest on the shells.

Interior of the pedicle valve.—The hinge teeth are stubby and situated on the medial edges of the hinge line bordering the delthyrial cavity. Dental lamellae are either absent or possibly present as very short lamellae, but stout hinge-tooth tracks invariably support the hinge teeth. The muscle field is not discernible, but a well developed myophragm is situated along the midline and extends anteriorly to about the midlength. The interior of the valve is smooth and strongly crenulated by the impress of the external plications.

Species assigned.—Plicoplasia cooperi Boucot, n. gen. and sp. *Metaplasia plicata* Weller, 1903, Geol. Survey N.J., Paleozoic Faunas, v. III, pp. 356–357, pl. XLVIII, figs. 7–12. *Spirifer planoconvexus* Knod, 1908, p. 550, pl. XXVII, figs. 10–12. *Spirifer tribuarius* Schuchert, 1913, Md. Geol. Survey, Lower Devonian, p. 414–415, pl. LXX, figs. 14–16. *Cyrtina? curupira* Rathbun, 1874, p. 242–243, pl. X, figs. 1 & b.

Distribution.—*Plicoplasia* is widely distributed in eastern North America, and is present in Bolivia, Brazil, and South Africa. *Ambocoelia umbonata* Cowper-Reed *non* Conrad (Cowper-Reed, 1903, p. 186; pl. 23, fig. 5) from the late Lower Devonian Bokkeveld beds belongs to *Plicoplasia* sp. cf. *P. planoconvexus*. The North American occurrences are exclusively in strata of Oriskany age, including the Grande Greve limestone, Glenerie limestone, Oriskany sandstone, lower part of the Moose River sandstone, and Seboomook slate.

PLICOPLASIA COOPERI Boucot, n. sp.
Pl. 1, figs. 13,14; pl. 2, figs. 1–5

Exterior.—The valves are unequally biconvex, with the brachial valve being very gently convex and the pedicle valve very strongly convex and inflated. The hinge line is straight, and the maximum width is located at the hinge line or slightly anterior to it. The outline of the shell is transversely elliptical. The lateral and anterior margins are evenly rounded. The brachial valve bears a median sulcus and the pedicle valve a corresponding fold. The interarea of the pedicle valve is apsacline, and the beak is gently incurved. The anterior commissure is sulcate and crenulate. The interarea of the brachial valve is anacline and about one-quarter the length of the interarea of the pedicle valve. The delthyrium is open and includes an angle of about 45 degrees. The fine ornamentation consists of concentric growth lines. A few specimens show what may be traces of radial striations. The coarse ornamentation of the brachial valve consists of one plication in the sulcus and two to three on each flank (including the plication that borders the sulcus). The plications are rounded in cross-section and are separated by deep, U-shaped interspaces.

Interior of the brachial valve.—The cardinalia consists of a prostrate, posteriorly directed, medially grooved, terminally bifid cardinal process laterally bounded by a pair of vertical crural plates. The posterior portions of the crural plates are fused to the base of the cardinal process. The crural plates form the medial edges of the dental sockets, fulcral plates form the bottom of the dental sockets, and the interarea forms the posterior face. The dental sockets are triangular in outline and form pits. The interior is smooth and deeply crenulated by the impress of the external plications.

Interior of the pedicle valve.—The hinge teeth are stubby and are situated on the medial edge of the hinge line, bordering the

---

EXPLANATION OF PLATE 1

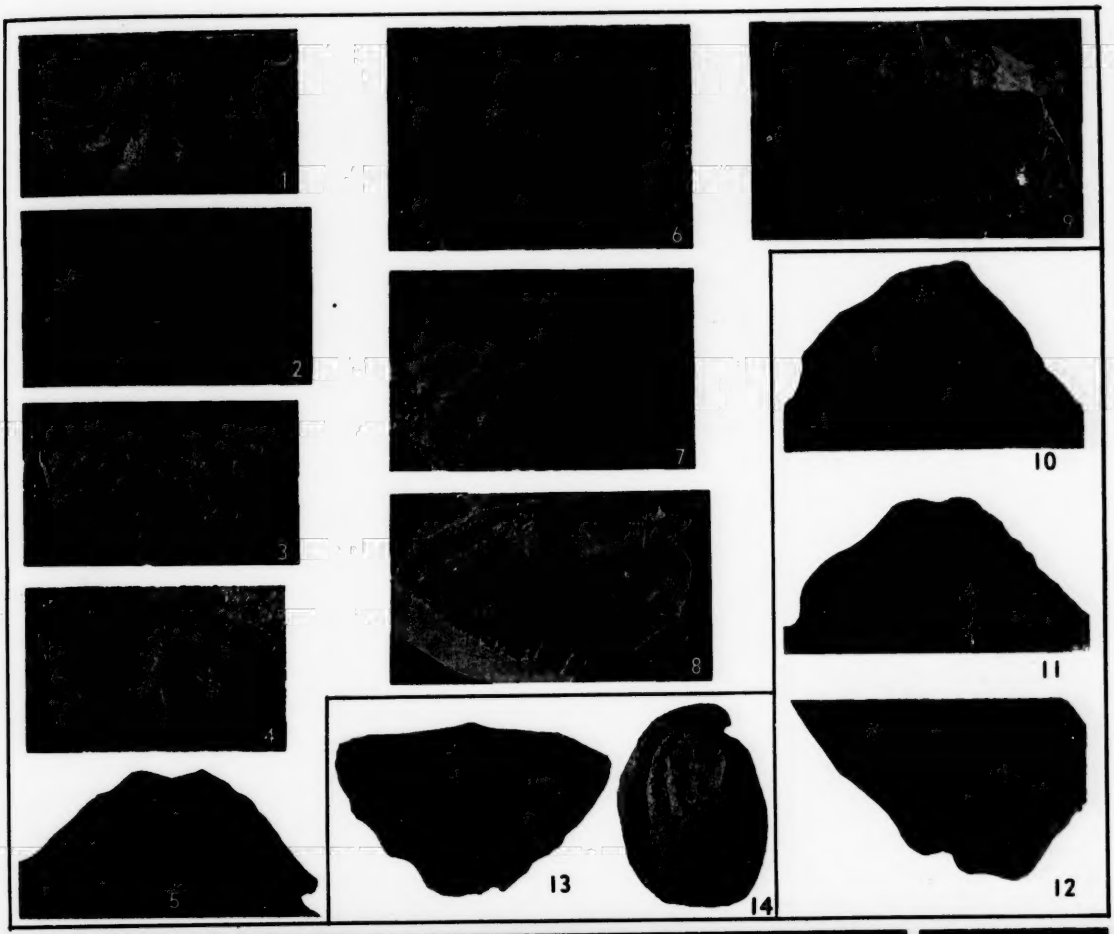
FIGS. *1–9*—*Plicoplasia plicata* (Weller, 1903). *1*, latex replica of exterior of pedicle valve, USNM No. 126087A, ×2. *2*, impression of interior of pedicle valve, USNM No. 126087B, ×2. *3*, latex replica of exterior of brachial valve, USNM No. 126114A, ×2. *4*, impression of interior of brachial valve, USNM No. 126114B, ×2. *5*, impression of interior of pedicle valve, posterior view, USNM No. 126259, ×3. *6*, latex replica of interior of brachial valve, USNM No. 126106, ×3. *7*, impression of interior of pedicle valve, USNM No. 126260, ×3. *8*, latex replica of interior of pedicle valve, USNM No. 126259, ×3. *9*, latex replica of interior of pedicle valve, USNM No. 126260, ×3.

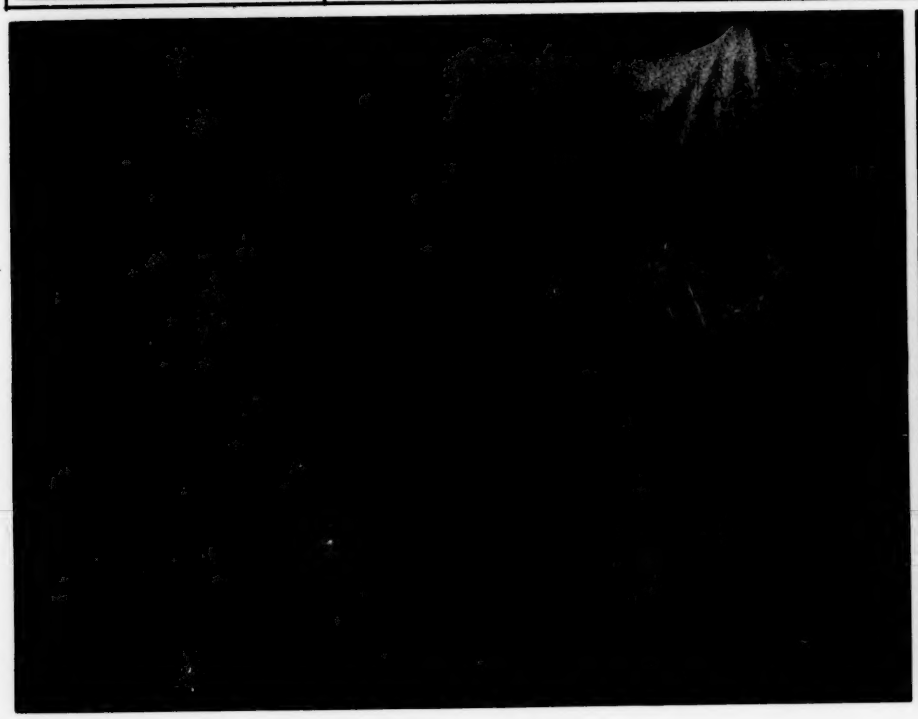
10–12—*Plicoplasia* sp. cf. *P. planoconvexa* (Knod, 1908). Bokkeveld sandstone. Gydo Pass, Ceres, Cape Prcvince, South Africa. *10*, impression of interior of pedicle valve, posterior view, Sedgwick Museum No. A2984–5, ×3. *11*, impression of interior of pedicle valve, posterior view, Sedgwick Museum No. A2984–5, ×3. *12* impression of interior of pedicle valve, Sedgwick Museum No. A2984–5, ×3.

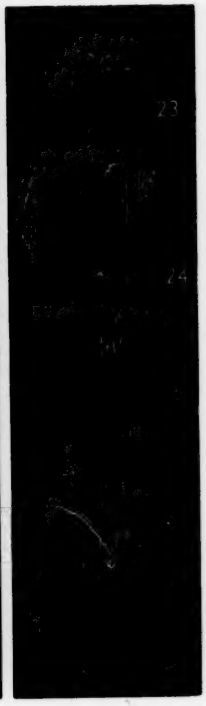
13,14—*Plicoplasia cooperi* Boucot, n. gen. and sp. Glenerie limestone. On N.Y. 9W, 1 mile north of Glenerie, 1 mile south of Cockburn, New York. *13*, interior of brachial valve, USNM No. 126096, ×3. *14*, exterior, side view, U.S.N.M. No. 126063B, ×3.

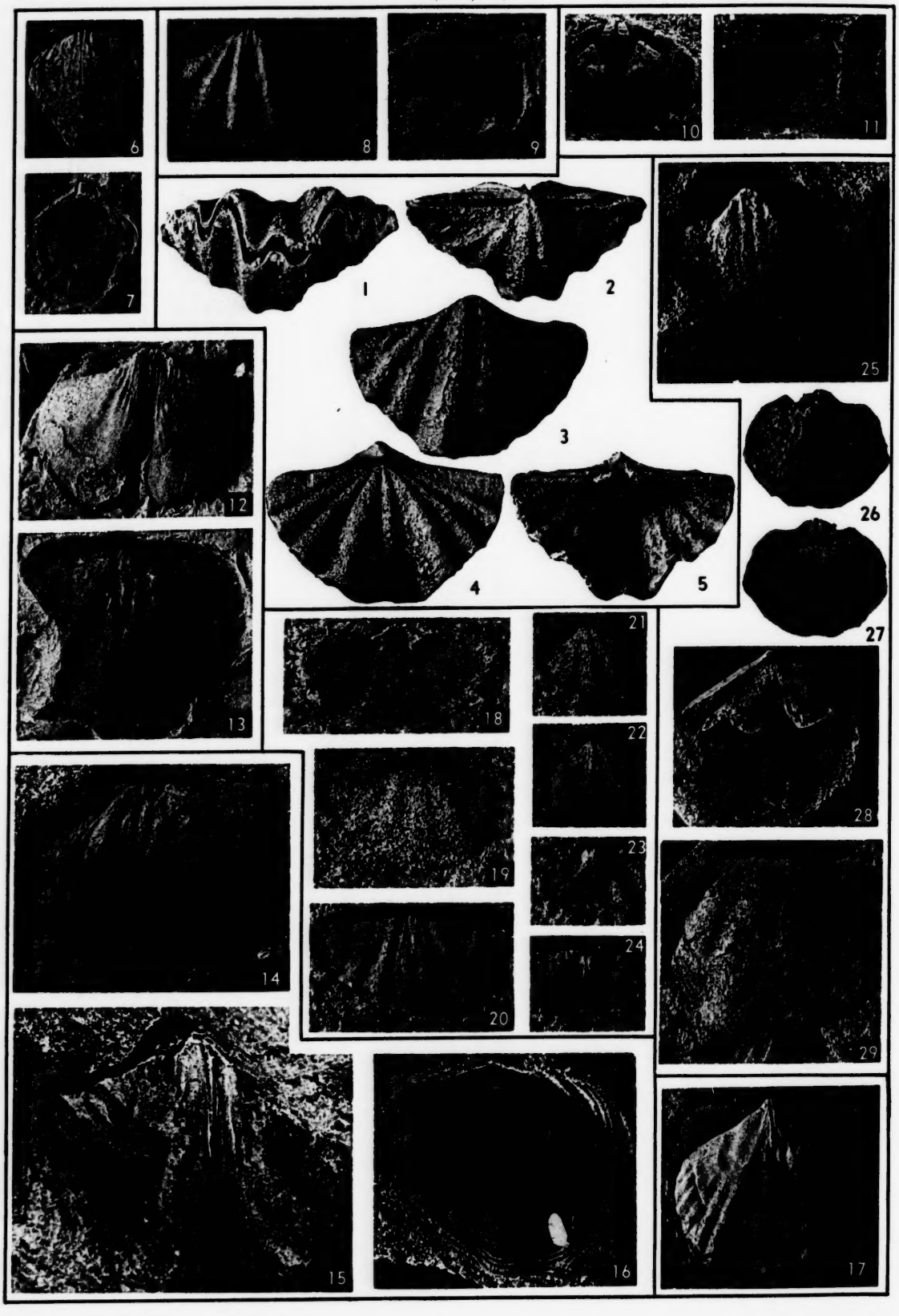
15–22—*Plicoplasia planoconvexa* (Knod, 1908). Strata of Lower Devonian age. Candelaria, Bolivia. Dereims Collection, Sorbonne, *15–19*, brachial, posterior, pedicle, anterior, and side views of the holotype, Sorbonne No. 58.002, all figures ×2. *20–22*, posterior, brachial, and pedicle views of the impression of an interior. Sorbonne No. 58.001, all figures ×3.

23–27—*Ambocoelia pseudoumbonata* Kozlowski, 1923. Strata of Lower Devonian age. Ayoayo, Bolivia. Dereims Collection, Sorbonne. Side, brachial, posterior, pedicle, and anterior views of the impression of an interior, Sorbonne No. 58.003, all figures ×3.


1
2
3
4
5
6
7
8
9
10
11
12
13
14




23
24


6
8
9
10
11
7
1
2
25
3
12
26
4
5
27
13
18
21
22
28
14
19
23
24
29
20
15
16
17

delthyrial cavity. The track of each tooth is submerged in a deposit of secondary material that lines the posterior face of the interior. Dental lamellae are absent. A myophragm extends from the delthyrial cavity to about the midlength and bisects the very poorly impressed, elongate muscle field. A pad of secondary material forms an apical callous in the posterior part of the delthyrial cavity. The interior is smooth and strongly crenulated by the impress of the external plications.

Comparison.—*P. cooperi* has a much deeper brachial sulcus, more pronounced fold, and less steeply rounded plications than either *P. plicata* or *P. planoconvexa.*

Distribution.—*P. cooperi* is known only from the Appalachian Province and is a relatively uncommon shell except near Glenerie, New York.

EXPLANATION OF PLATE 2

FIGS. *1–5*—*Plicoplasia cooperi* Boucot, n. gen. and sp. Glenerie limestone. On N.Y. 9W, 1 mile north of Glenerie, 1 mile south of Cockburn, New York. *1–3,5*, pedicle, posterior, anterior, and brachial views of exterior, USNM No. 126063B, all figures ×3. *4*, interior of a pedicle valve, USNM No. 126096, ×3.

6,7—*Nanothyris* sp. cf. *N. subglobosa* (Weller, 1903). Strata of New Scotland age. Béland's locality No. 39, Bonaventure County, Quebec. *6*, impression of interior of brachial valve, Redpath Museum No. 2.3563(C), ×3. *7*, impression of posterior end of pedicle valve interior and of brachial valve exterior, Redpath Museum No. 2.3563(B), ×3.

8,9—*Plicoplasia planoconvexa* (Knod, 1908). Strata of late Early Devonian age containing *Australocoelia tourteloti, Mutationella* sp., *Schuchertella* sp., *Chonostrophia? sp.*, and *Acrospirifer* or *Howellella* (see Boucot & Gill, 1956, p. 1176). Comparapa-Tunal region, Department of Santa Cruz, Bolivia; collected by H. Tourtelot and Rodriguez in 1953 (their locality No. T53B-38), cited by them as follows: "fossils were found in float . . . stream bottom . . . may have come from anywhere in the section . . . Section on north side of ridge between Comparapa and Tunal, and on the slope into the Rio Pulgnina. Comparapa is at Kilometer 254 on the Cochabamba-Santa Cruz highway. Tunal is about 10 km by horseback northeast of Comparapa." *8*, impression of exterior of pedicle valve, USNM No. 126522, ×3. *9*, impression of interior of pedicle valve, USNM No. 126522, ×3.

10,11—*Skenidium* sp. Strata of New Scotland age. Béland's locality No. 37, Bonaventure County, Quebec. *10*, impression of interior of brachial valve, Redpath Museum No. 2.3568(A), ×10. *11*, impression of exterior of brachial valve, Redpath Museum No. 2.3568(B), ×10.

12,13—*Metaplasia paucicostata* (Schuchert, 1913). Shriver chert. Cash Valley, Maryland. *12*, impression of interior of pedicle valve, USNM No. 61738, ×3. *13*, impression of interior of brachial valve, USNM No. 61738, ×3.

14–16—*Spinoplasia gaspensis* Boucot, n. gen. and sp. Strata of New Scotland age. Béland's locality No. 37, Bonaventure County, Quebec. *14*, impression of interior of brachial valve, Redpath Museum No. 2.3560(A), ×10. *15*, impression of interior of pedicle valve, Redpath Museum No. 2.3561(B), ×10. *16*, impression of exterior of brachial valve, Redpath Museum No. 2.3560(B), ×10.

17—*Leptocoelia* sp. aff. *L. flabellites* (Conrad). Strata of New Scotland age. Béland's locality No. 37, Bonaventure County, Quebec. Impression of interior of pedicle valve, Redpath Museum No. 2.3562, ×2.

18–24—*Metaplasia minuta* Boucot, n. sp. Upper part of Moose River sandstone. USGS Silurian-Devonian locality No. SD-2750, Brassua Lake quadrangle, Somerset County, Maine. *18*, latex replica of interior of brachial valve, USNM No. 126086A, ×4. *19*, latex replica of exterior of brachial valve, USNM No. 126086B, ×4. *20*, impression of interior of brachial valve, USNM No. 126086A, ×4. *21*, latex replica of exterior of pedicle valve, USNM No. 126067A, ×3. *22*, impression of interior of pedicle valve, USNM No. 126067B, ×3. *23*, latex replica of exterior of pedicle valve, posterior view, USNM No. 126110B, ×4. *24*, impression of interior of pedicle valve, posterior view, USNM No. 126110C, ×4.

25–29—*Metaplasia* sp. cf. *M. paucicostata* (Schuchert, 1913). Lower part of Moose River sandstone. USGS locality No. SD-2806, northwest ninth of Pierce Pond quadrangle, in old sluiceway shown on map as western outlet of McKenney Ponds, Somerset County, Maine. *25*, latex replica of interior of pedicle valve, USNM No. 126115C, ×3. *26*, impression of interior of pedicle valve, USNM No. 126115B, ×4. *27*, impression of interior of brachial valve, USNM No. 126115B, ×4. *28*, latex replica of exterior of pedicle valve, USNM No. 126115A, ×3. *29*, impression of interior of pedicle valve, USNM No. 126115C, ×5.

Holotype.—USNM No. 126063B, from New York Route 9W, one mile north of Glenerie, one mile south of Cockburn, New York.

Figured specimens.—USNM Nos. 126063, 126096.

Unfigured specimens.—USNM No. 126095. The specimens figured by Cooper (in Shimer & Shrock, 1944, pl. 126, figs. 40–43) as *Metaplasia pyxidata* Hall belong to *P. cooperi.*

PLICOPLASIA PLICATA (Weller, 1903)
Pl. 1, figs. 1–9

Exterior.—The brachial valve is gently convex to flat and the pedicle valve is strongly convex, subpyramidal. The greatest width is located at the hinge line, which is straight, or slightly anterior to the hinge line. The shells are transversely elliptical in outline. The brachial valve bears a broad, shallow, median sulcus, the pedicle valve a broad, low, median fold. The anterior commissure is crenulate and weakly sulcate. The lateral and anterior margins are evenly rounded. The coarse ornamentation consists of plications which have a rounded cross-section and are separated by wide, rounded interspaces. One plication is situated in the sulcus, and each flank bears three to four lateral plications, including the strong one that bounds the fold or sulcus laterally. The plications bounding the fold are larger than the other plications present on the shell. The interarea of the pedicle valve is apsacline and straight to gently incurved. The interarea of the pedicle valve is about 5 times as long as that of the brachial valve. The interarea of the brachial valve is gently anacline. The posterior margin of the interarea of the brachial valve is parallel to the hinge line; that of the pedicle valve makes an angle of about 45 degrees with the hinge line. The fine ornamentation consists of concentric growth lines which are relatively lamellose anteriorly. The delthyrium is open and includes an angle of about 30 degrees.

Interior of the brachial valve.—The cardinalia consists of a prostrate, posteriorly directed, medially grooved, terminally bifid and striate cardinal process laterally flanked by baso-medially converging crural plates, whose lower edges are parallel. The dental sockets are formed medially by the crural plates, antero-laterally by fulcral plates (which form their bottom as well), and posteriorly by the interarea. The dental sockets are triangular in cross-section. A myophragm bisects the valve, but the muscle impressions are not discernible. The interior of the valve is smooth and crenulated by the impress of the external plications.

Interior of the pedicle valve.—Stout hinge teeth are situated on either side of the median edge of the hinge line. The hinge teeth are basally supported by hinge-teeth tracks which bound the lateral margins of the delthyrial cavity. Dental lamellae are absent. A myophragm bisects the muscle field and extends anteriorly to about the midlength. The muscle field is weakly discernible. The interior is smooth and crenulated by the impress of the external plications. An apical callous fills the posterior portion of the delthyrial cavity. The muscle field is elongate and very narrow.

Distribution.—*P. plicata* is widely distributed in strata of Oriskany age in Eastern North America (Grande Grève limestone, Glenerie limestone, Oriskany sandstone, lower part of the Moose sandstone, and Seboomook slate[1]).

Comparison.—*P. plicata* has previously been contrasted with *P. cooperi. P. plicata* differs from *P. planoconvexa* in having narrower interspaces between the lateral plications externally and in lacking medially conjunct crural plates and relatively platelike hinge teeth internally. *P. plicata* has a much greater development of apical callous than *P. planoconvexa. "Spirifer" tribuarius* Schuchert, 1913, is probably a synonym of *P. plicata*, but lack of comparative material prevents the suppression of *"S." tribuarius* at this time.

PLICOPLASIA PLANOCONVEXA
(Knod, 1908)
Pl. 1, figs. 15–22; pl. 2, figs. 8,9

Exterior.—The valves are unequally bi-

[1] Andrew Griscom of the U. S. Geological Survey has collected a pedicle valve belonging to *P. plicata* in association with *Leptocoelia flabellites* from the Seboomook slate. The locality is about three miles north of the southern tip of Sandy Point, Chesuncook Lake, Grant Farm quadrangle, Maine, at an exposure on the west side of the Lake that is submerged except during very low water.

convex, with the brachial being gently convex and the pedicle subpyramidal, highly convex. The maximum width is situated at or slightly anterior to the straight hinge line. The interarea of the brachial valve is anacline and about one-fifth the length of the steeply apsacline, gently incurved pedicle interarea. The delthyrium is open and includes an angle of about 45 degrees. The brachial valve bears a broad shallow sulcus that is largely filled by a flat, low, median plication. The pedicle valve bears a broad fold that is medially indented by a broad groove. The flanks bear about three lateral plications, rounded in cross-section and separated from each other by U-shaped interspaces. The anterior commissure is uniplicate and crenulate. The fine ornamentation consists of concentric growth lamellae, which are most prominent anteriorly. The shells have a transversely elliptical outline. The lateral and anterior margins are evenly rounded.

Interior of the brachial valve.—The cardinalia consists of a flattish, longitudinally striate, short cardinal process laterally and anteriorly bounded by shallowly inclined crural plates that meet antero-medially. The crural plates form a short cruralium. The dental sockets are laterally directed; they are formed from the outer face of the crural plates and the anterior face of the hinge line. Fulcral plates have not been observed. A laterally directed spire is present. The interior is smooth and deeply crenulated by the impress of the external ornamentation. The muscle field is weakly impressed and elongate; it extends anteriorly to the midlength. A slender pair of anterior adductor impressions is visible near the midlength on either side of a low myophragm.

Interior of the pedicle valve.—The delthyrium is unmodified except by a low myophragm which extends anteriorly to about the midlength. The muscle field is not apparent. The stout hinge teeth are basally supported by a blade-like hinge-tooth track or possibly by very short dental lamellae. The interior is smooth and strongly crenulated by the impress of the external ornamentation.

Comparison.—*P. planoconvexa* has been contrasted previously with *P. plicata.*

Distribution.—*P. planoconvexa* is known from Bolivia with certainty and may be known from Brazil if *P. curupira* is conspecific. *P. planoconvexa* (Knod, 1908) is based on Bolivian material and is possibly a junior synonym of *P. curupira* (Rathbun, 1874) which is based on Brazilian material, but in the absence of topotype material of the latter it is impossible to be certain. It is likely that *Ambocoelia umbonata* Reed *non* Conrad (Reed, 1903, p. 186) also belongs to *P. planoconvexa*, but the single specimen available is too poorly preserved to afford an adequate basis for positive specific identification.

Types.—The holotype is here designated as Collection de Géologie de la Sorbonne No. 58.002 and the paratypes as Nos. 58.001 and 58.004, all from the Dereims Collection with the locality notation "Candelaria".

Figured specimens.—Sedwick Museum No. A2984–5 and U. S. National Museum No. 126522.

STRATIGRAPHIC SUMMARY

Ambocoeliniinids are first known from the étage de Borszczow in Podolia (Kozlowski, 1929, p. 201), where strata that the present writer considers to be of lower Gedinne age (Boucot, in preparation), contain a form belonging to *Ambocoelia sensu strictu. Ambocoelia sensu strictu* (pl. 1, figs. 23–27, this paper) is also known from the late Early Devonian of South America (Kozlowski, 1923, p. 95–96) and Czechoslovakia (Havlicek, 1956, p. 65–66) but has not been found elsewhere except in the Middle Devonian to Mississippian of North America. The weakly plicated ambocoeliinid genus *Metaplasia* is known from strata of Oriskany and Onondaga age (=Siegen and Ems) in eastern North America. The strongly plicated ambocoeliinid genus *Plicoplasia* is known from strata of Oriskany age in eastern North America and from strata of late Early Devonian age in Bolivia, Brazil and South Africa. The weakly plicated, spinose ambocoeliinid genus *Spinoplasia*; is known from strata of New Scotland age in Gaspé.

ACKNOWLEDGMENTS

I am most grateful to the John Simon Guggenheim Memorial Foundation for a

Fellowship that permitted study in European museums of rare material from the Malvinocaffric Province. Professor Pierre Pruvost of the Sorbonne kindly permitted the loan of material previously studied and described by Knod. This material is part of the Dereims Collection of the Sorbonne. The Curator of the Sedgwick Museum, Cambridge University, kindly provided photographs of a specimen of *Plicoplasia* sp. cf. *P. planoconvexa* (Knod, 1908) described by Reed from the Bokkeveld sandstone. Dr. Jacques Beland, Quebec Department of Mines, kindly submitted the *Spinoplasia*-bearing material from Gaspé for study. A grant from the Permanent Science Fund of the American Academy of Arts and Sciences assisted in making the photographs of the austral specimens, and I am indebted to Nelson W. Shupe through the courtesy of the U. S. Geological Survey for the photographs of the North American ambocoeliinids used in this paper. Professor H. B. Whittington, Harvard University, very kindly provided the photographs of *Spinoplasia* and *Skenidium* from Gaspé.

REFERENCES

BOUCOT, A. J., 1954, Age of the Katahdin granite: Amer. Jour. Sci., v. 252, p. 144–148.

——, (in preparation) Gedinne Brachiopoda of Belgium.

——, & GILL, E. D., 1956, *Australocoelia*, a new Lower Devonian brachiopod from South Africa, South America, and Australia: Jour. Paleontology, v. 30, p. 1173–1178.

COOPER, G. A., 1944, Phylum Brachiopoda (*in* Index fossils of North America), John Wiley and Sons, Inc., pp. 277–365.

DUNBAR, C. O., 1919, Stratigraphy and correlation of the Devonian of western Tennessee: Tenn. Geol. Survey, Bull. 21.

HALL, J., & CLARKE, J. M., 1893, An introduction to the study of genera of Paleozoic Brachiopoda: N. Y. Geol. Survey, Pal. 8, Pt. 2.

HAVLICEK, V., 1956, The brachiopods of the Branik and Hlubocepy Limestones in the immediate vicinity of Prague: Sbornik Ustredniho Ustavu Geologickeho, v. 22, p. 535–665.

KNOD, R., 1908, Beiträge zur Geologie und Paläontologie von Sudamerika: Neu. Jahrb. f. Min., Beil. Bd. 25, p. 493–600.

KOZLOWSKI, R., 1923, Faune Devonienne de Bolivie: Annales de Paleontologie, v. 12, fasc. 1–2.

——, 1929, Les brachiopodes Gothlandiens de la Podolie Polonaise: Pal. Polonica, T. 1.

RATHBUN, R., 1874, On the Devonian Brachiopoda of Ereré, Province of Para, Brazil: Bull. Buffalo Soc. Nat. Sci., v. I, p. 236–261.

REED, F. R. C., 1903, Brachiopoda from the Bokkeveld Beds: Ann. South African Mus., v. 4, p. 165–197.

MANUSCRIPT RECEIVED DECEMBER 7, 1957.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 25–28, PL. 3, 1 TEXT-FIG., JANUARY 1959

A NEW FAMILY AND GENUS OF SILURIAN ORTHOTETACID BRACHIOPODS

A. J. BOUCOT[1]
Department of Geology and Geophysics, Massachusetts Institute of Technology

ABSTRACT—Study of Silurian and Devonian orthotetacid brachiopods from northern Maine has brought into question the proper generic identity of specimens usually referred to *Fardenia* in the Silurian of North America and Europe. Study of the Silurian material demonstrated that most specimens belong to a previously undescribed genus, *Chilidiopsis*, here assigned to a new family, which is generically distinct from *Fardenia* though probably derived from it.

Study of the collections in the U.S. National Museum suggests that the new genus described below is the commonest orthotetacid in the Silurian of North America and western Europe, but that *Schellwienella*-like forms also occur with it. *Schellwienella*-like forms are rare in the Silurian but are more abundant in rocks of post-Silurian age.

The type species of the new genus, "*Fardenia*" *reedsi* Amsden, 1951, is well illustrated by Amsden (1951, pl. 17); "*Schuchertella*" *roemeri* Foreste, 1909, here assigned to the new genus, is also well illustrated by Amsden (1949, pl. V, figs. 23–28). The reader is referred to these papers for additional illustrations of the new genus.

Superfamily ORTHOTETACEA
Family CHILIDIOPSIDAE
Boucot, n. fam.

Diagnosis.—Impunctate[2] orthotetacids in which the brachial valve possesses a large chilidium and the pedicle valve possesses a very small pseudodeltidium which may lap over into the bottom of the delthyrial cavity, where it apparently serves as the pedicle callist.

Discussion.—The only genus assigned is *Chilidiopsis*, which is now known only from beds of Upper Llandovery to Lower Ludlow age in eastern North America[3] and Europe.

Genus CHILIDIOPSIS Boucot, n. gen.
Pl. 3, figs. 1,2

Type species.—*Fardenia reedsi* Amsden.

Diagnosis.—Biconvex to resupinate orthotetacids possessing a large, tentlike chilidium surrounding the cardinalia posteriorly, and a concave, laterally striated, subhorizontal, triangular plate at the posterior end of the delthyrial cavity. This plate fills the apex of the delthyrium and probably serves as a pseudodeltidium externally and a pedicle callist internally. In the pedicle valve, the plate is variably developed, being very conspicuous and thickened in some specimens but inconspicuous and thin in others. The shell is impunctate as determined by study of a thin section (USNM No. 136243) prepared from a Waldron shale specimen, and from study of numerous specimens with well-preserved interiors.

Exterior.—Gently biconvex orthotetacids with greatest width at the hinge line, large shells tending to be resupinate. The outline of the shell is elliptical to subcircular. The pedicle interarea is apsacline, and the brachial interarea is anacline. The notothyrium is covered by a large and convex chilidium. The delthyrium has a small pseudodeltidium-like structure at the apex; this pseudodeltidium-like structure extends into the delthyrial cavity anteriorly where it probably serves as the pedicle callist. Ornament consists of primary, secondary, and tertiary costellae originating by both implantation and bifurcation. All costellae are crossed by concentric filae. The brachial

[1] Publication authorized by the Director, U. S. Geological Survey.

[2] Williams (1956, p. 254) has been unable to find evidence of pseudopunctae in Silurian orthotetacids, but does find taleolae in younger specimens assigned to *Schellwienella* (written comm. 1957).

[3] The writer considers the Upper Llandovery equivalent to the Clinton group of New York, the Wenlock to the Rochester shale, and the Ludlow to the Lockport and Guelph dolomites plus the Salina group and the Cobleskill limestone.

interarea may be higher than that of the pedicle valve.

Brachial interior.—Stout brachiophores diverge at an angle of about 90 degrees, the brachiophores being supported by thin crural plates. The bottom of the dental socket is partitioned off by a socket plate, and the cardinal process is bifid, erect, and surrounded posteriorly by the chilidium. The muscle field is divided medially by a broad undulation of secondary material. The muscle field is quadripartite and restricted to the posterior half of the shell.

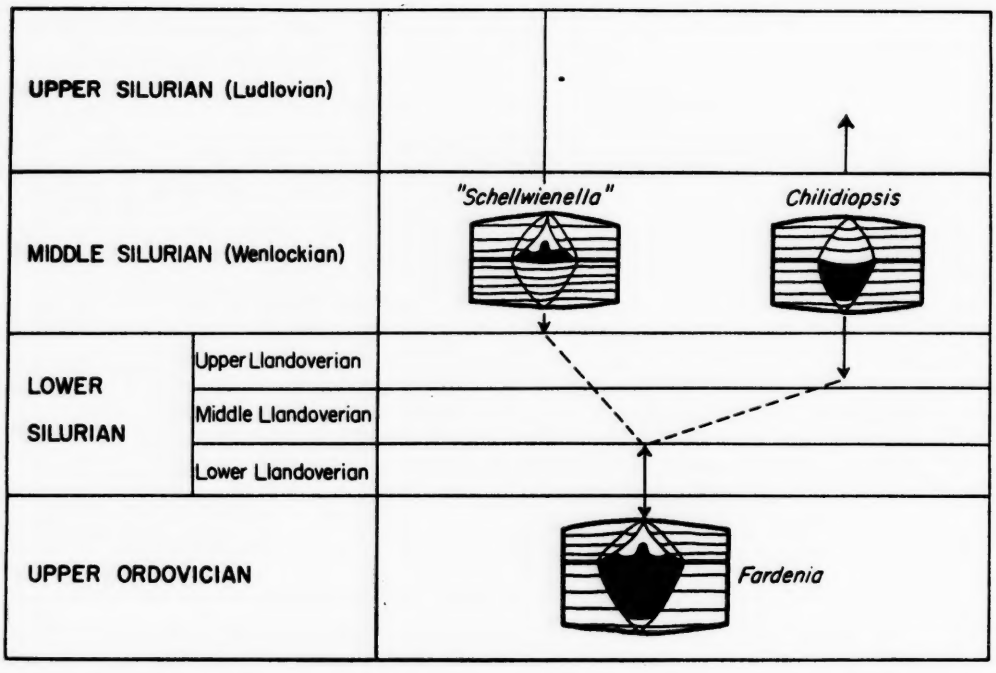
Pedicle interior.—Stout hinge teeth are supported by short, thin dental plates. The delthyrial cavity may be occupied posteriorly by a concave, subhorizontal, laterally striated plate that probably served as the pedicle callist. The anterior margin is covered with rounded crenulations separated by narrow interspaces. The muscle field is moderately well impressed posteriorly, but does not extend anteriorly beyond the limits of the dental plates.

Occurrence.—Eastern North America and western Europe.

Geologic Range.—Uppermost Llandovery (C_4) to Lower Ludlow (Henryhouse formation); Lower Silurian to Upper Silurian.

Comparison.—*Chilidiopsis* lacks the well-developed and prominent pseudodeltidium of the other genera of post-Ordovician orthotetacids. *Fardenia* does not posses a large chilidium, but does have a pair of small discrete chilidial plates lateral to the lobes of the cardinal process. *Fardenia* also has a small, moderately well-developed pseudodeltidium resembling that of *Chilidiopsis.* The dental plates of *Fardenia* are longer than those of *Chilidiopsis.*

Remarks.—*Chilidiopsis* probably has been derived from a relatively generalized form like *Fardenia* (see text-fig. 1) by the enlargement and eventual median fusion of the discrete chilidial plates found in *Fardenia.* A *Fardenia*-like form may well have also given rise to the other genera (text-fig. 1) of the Orthotetacea by the development of a large pseudodeltidium from the small pseudodeltidium present in *Fardenia,* at the same time retaining the small discrete chilidial plates of *Fardenia. Fardenia goef-*



TEXT-FIG 1—Diagnostic features and geologic ranges of *Fardenia, Chilidiopsis,* and "*Schellwienella.*"

freyi Williams 1951, from the Gasworks mudstone (of Lower Llandovery age), has relatively large, discrete chilidial plates, as opposed to the small discrete chilidial plates of *Fardenia scotica*, of late Ordovician age (Drummock group), and suggests that by further enlargement and eventual fusion the evolution of a *Chilidiopsis*-like form could have been achieved.

"*Fardenia*" *attenuata* Amsden, 1951, from the late Silurian Henryhouse formation, does not belong to *Chilidiopsis*. It most closely resembles *Schellwienella*, which also has a large pseudodeltidium and tiny chilidium. "*F.*" *attenuata* lacks the very prominent dental lamellae of forms like "*Schellwienella*" *woolworthana*. "*F.*" *attenuata* possesses a large pseudodeltidium, in contrast to the small structure present in true *Fardenia*. Schuchertellids, i.e., orthotetacids lacking dental lamellae, first appear in the lower Gedinne and its equivalents, presumably being derived from a schellwienellid ancestor.

Fardenia sensu strictu is known only from rocks of Upper Ordovician[4] and Lower Llandovery age; no unquestioned specimens are known to the writer from rocks of Upper Llandovery age. The earliest *Schellwienella*-like orthotetacid known to the writer occurs in the Wenlock limestone at Dudley, England (British Museum Nos. B765 and B3942).

The Gedinnian forms assigned to "*Schuchertella*" *pecten* (Asselberghs, 1930, p .30–31) were found by the writer to have a large pseudodeltidium, which precludes their belonging to *Chilidiopsis pecten* (Linnaeus).

Kozlowski's (1929, p. 105–107) "*Schellwienella*" *praeumbraculum*, known from the lowest Devonian of Podolia, possesses a large pseudodeltidium, and does not belong to *Chilidiopsis*. Fuchs (1919, p. 65–66) ascribes a large pseudodeltidium to his German Gedinnian species "*Orthotetes*" *euzona* Fuchs 1919, which precludes an assignment to *Chilidiopsis*.

The genus *Coolinia* Bancroft ms (see Lamont 1949, p. 7) is based on the poorly known species *Orthis? applanata* Salter, 1846 (in McCoy 1846, p. 72, Pl. V, figs. Ia–e). Specimens of *O.? applanata* from the type locality that showed the nature of the chilidial and deltidial plates were not available for study, although the material in the collections of H. M. Geological Survey, London clearly shows that *C. applanata* is an orthotetacid. Mr. John C. Harper, The University of Liverpool, kindly loaned the writer specimens that may belong to *C. applanata* but were collected about five miles west, at Benlugmore, of the type locality at Coolin, Cong, Ireland. Harper's specimens belong to an orthotetacid possessing a small pseudodeltidium, but the nature of the chilidial plates in this material were not evident. Harper's specimens of a brachial valve may have small, discrete chilidial plates suggesting an assignment to *Fardenia*, but no final conclusion could be reached on the basis of this one specimen. Harper's material probably comes from strata of Upper Llandovery age that would be predicted to contain *Chilidiopsis* rather than *Fardenia*. If *Coolinia applanata* upon restudy of topotype material is found to have a large chilidium it should probably be concluded that the genus *Chilidiopsis* belongs in the synonomy of *Coolinia*, but pending further information the writer deems it unwise to assign the common Silurian orthotetacid to the poorly known genus *Coolinia* in view of the previous confusion that resulted from assigning it to *Fardenia*.

Acknowledgments.—The writer is grateful to the John Simon Guggenheim Foundation, which provided a Fellowship for the study of European Silurian and Devonian brachiopods. Dr. Archie Lamont, Carlops, Midlothian, Scotland, very generously conducted the writer to the type locality for *Fardenia scotica* Lamont 1935 and helped him to collect a good sample of this species. For permission to study collections of Silurian and Devonian brachiopods, the writer is indebted to Dr. Ethel D. Currie, Hunterian Museum, Glasgow; Dr. Gunnar Henningsmoen, Paleontological Museum, Oslo; Professor Marius Lecompte, Institut Royal des Sciences Naturelles de Belgique, Brussels; Dr. Helen Muir-Wood, British Museum (Natural History), London; Dr. Tor Ørvig, Riksmuseum, Stockholm; and Dr. Jeremy Smith, H.M. Geological Survey, London.

[4] The generic identity of Twenhofel's (1928, p. 197–198) *Schuchertella gamachiana* could not be determined by the writer.

Species Assigned to *Chilidiopsis*

Fardenia reedsi AMSDEN, 1951, Jour. Paleontology, v. 25, no. 1, p. 84, pl. 17, figs. 1–8.
Strophomena subplana CONRAD, 1842, Jour. Acad. Nat. Sci. Phila., v. 8, p. 258.
Schuchertella roemeri FOERSTE, 1909, Bull. Sci. Lab. Denison Univ., v. 14, p. 82–83, pl. 2, figs. 27 a-c.
Fardenia sp. AMSDEN, 1951, Jour. Paleontology, v. 25, no. 1, p. 85, pl. 17, fig. 28.
Anomia pecten LINNAEUS, 1767, Syst. Nat., 10th ed., v. 1, pt. 2, p. 1152.
Strophomena alterniradiata SHALER, 1865, Bull. Mus. Comp. Zoology, v. 1, no. 4, p. 63.

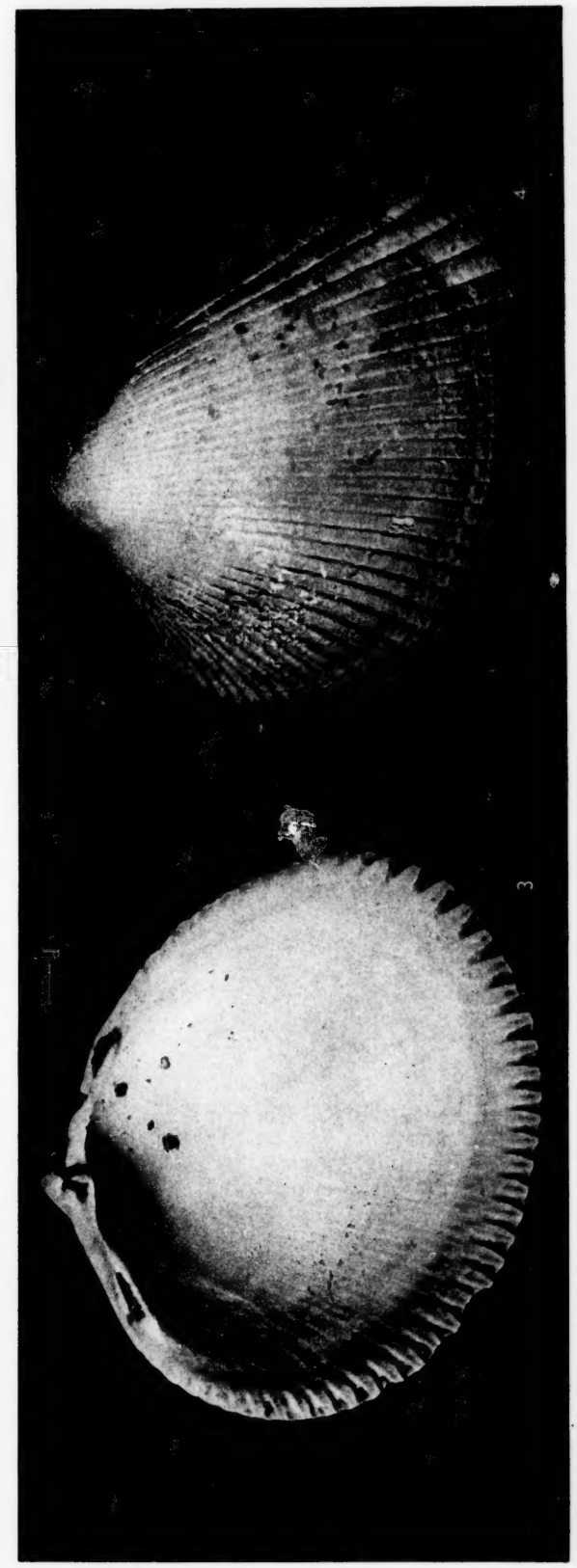
REFERENCES CITED

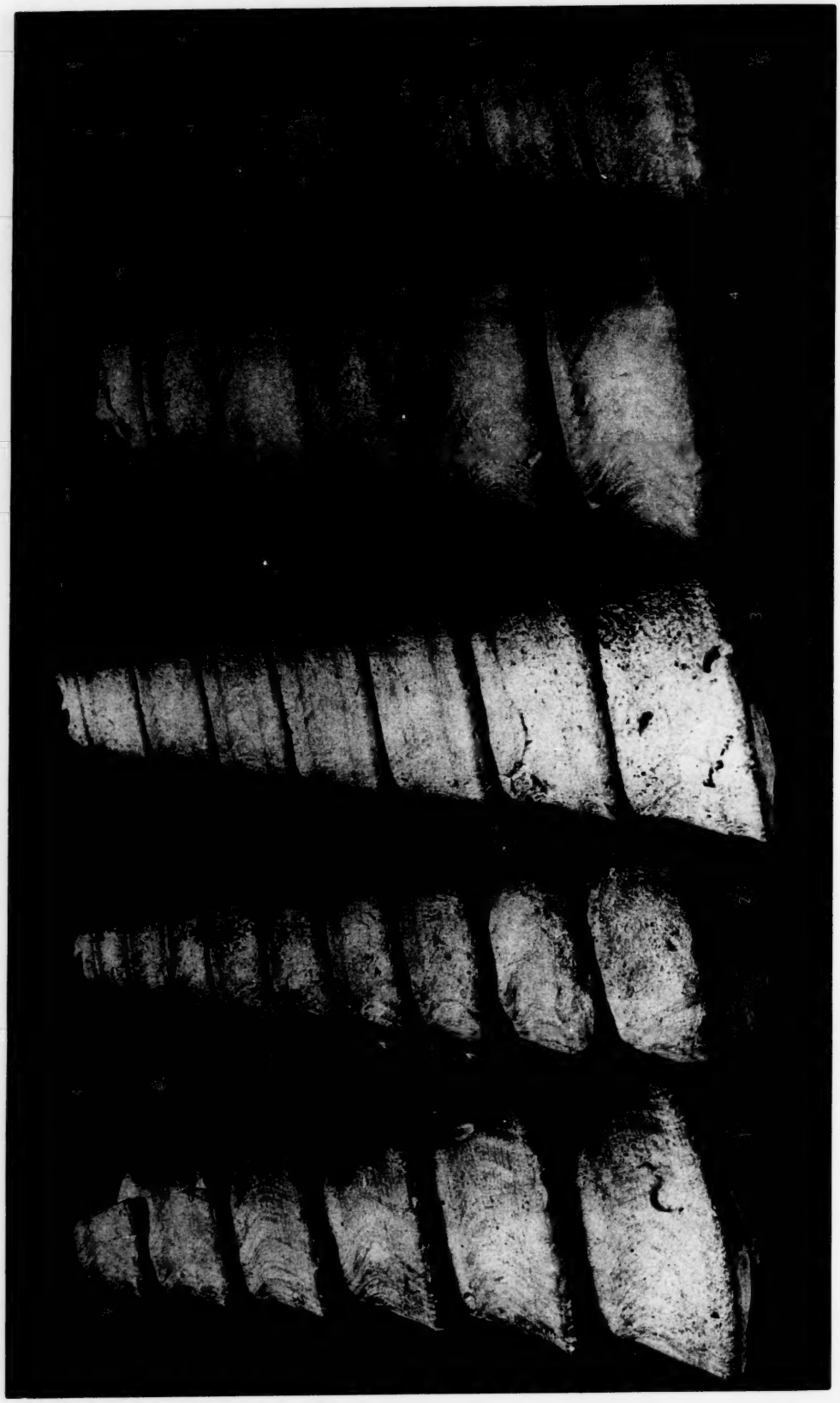
AMSDEN, T. W., 1949, Stratigraphy and Paleontology of the Brownsport formation (Silurian) of western Tennessee: Peabody Mus. Nat. History, Yale Univ., Bull. 5.
——, 1951, Brachiopods of the Henryhouse formation (Silurian) of Oklahoma: Jour. Paleontology, v. 25, no. 1, p. 69–96.
ASSELBERGHS, E., 1930, Mem. Mus. Nat. Hist. de Belg., tome 41.
FUCHS, A., 1919, Beitrag zur Kenntniss der Devonfauna der Verse- und der Hobräcker Schichten des sauerländischen Faciesgebietes: Jahrb. Preuss. Geol. Land. für 1918, Band 39, T.I., Heft. 1, p. 58–95.
KOZLOWSKI, R., 1929, Les Brachiopodes Gothlandiens de la Podolie Polonaise: Palaeontologia Polonica, T. I.
LAMONT, A., 1935, The Drummock group, Girvan; A stratigraphical revision, with description of new fossils from the lower part of the group: Trans. Geol. Soc. Glasgow, v. 19, pt. 2, p. 288–334.
——, 1949, Welsh Valentian brachiopods, p. 1–10, privately printed.
MCCOY, F., 1846, A synopsis of the Silurian fossils of Ireland: Dublin.
TWENHOFEL, W. H., 1928, Geology of Anticosti Island: Geol. Survey Canada, Mem. 154, 481 p.
WILLIAMS, ALWYN, 1956, The calcareous shell of the brachiopods and its importance to their classification: Biol. Reviews, v. 31, p. 243–387.

MANUSCRIPT RECEIVED DECEMBER 7, 1957.

EXPLANATION OF PLATE 3

FIGS. *1,2—Chilidopsis* sp. *1*, interior of pedicle valve, ×3. Note the small pseudodeltidium at the apex of the delthyrium and the gently convex, striated plate at the posterior end of the delthyrial cavity. Decatur limestone. Quarry on north side of Tenn. 20, 0.7 miles southeast of junction of Tenn. highways 20 and 13, 1½ miles south southeast of Linden, Tennessee. USNM No. 126609. *2*, interior of brachial valve, ×3. Note the large chilidium which posteriorly surrounds the lobes of the cardinal process. Decatur limestone. Quarry on north side of Tenn. 20, 0.7 miles southeast of junction of Tenn. highways 20 and 13, 1½ miles southeast of Linden, Tennessee, USNM No. 126609.
3,4—Cerastoderma chancellorensis, n. sp. Height of the shell 22 mm.; length, 23 mm.





JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 29–32, PL. 4, JANUARY 1959

SOME NEW SPECIES OF MIOCENE MOLLUSCA FROM MARYLAND

JOHN OLEKSYSHYN
Department of Geology, Boston University

ABSTRACT—*Turritella calvertensis*, n. sp. *T. calvertensis marylandica*, n. subsp., *T. calvertensis plumpointensis*, n. subsp., and *T. indenta chesapeakensis*, n. subsp., are described from the Calvert Formation of the Chesapeake Bay region, Maryland; *Turritella variabilis chancellorensis*, n. subsp., and *Cerastoderma chancellorensis*, n. sp. from the St. Mary's Formation at St. Mary's City, Maryland.

INTRODUCTION

EFFORTS to correlate the Miocene and Pliocene deposits of the Atlantic Coastal Plain of North America and sediments of the same ages of Europe have been made by Dr. Julia Gardner. The main difficulties of such correlation, according to Dr. Gardner, are the absence of a good standard section of marine deposits in temperate and warm regions of Europe, which would be most closely comparable to the majority of Miocene and Pliocene deposits of the Atlantic Coastal Plain of North America.

Stratigraphic investigations in European countries during the last four decades have done much to clarify the stratigraphic succession in late Cenozoic deposits. The macro-, and microfauna, and tectonism in the Vienna and the Graz basins in Austria, the Pannonian Basin in Hungary, and certain regions of southern Rumania and southern Ukraine, have supplied excellent data to establish the boundary between Miocene and Pliocene strata.

Correlation of Miocene deposits of the Atlantic Coastal Plain of North America and Europe should be based not only on the literature dealing with corresponding regions but also on the faunas of both continents, because the same genera have often been given different names, causing confusion in the correlation of the strata. For this reason I started to collect the Miocene fauna of the Atlantic Coastal Plain and will attempt to obtain comparable fossils from some characteristic regions of Europe through the medium of exchange. Up to this time I have collected several suites of Miocene fossils in southern New Jersey, in the Chesapeake Bay region and in the region around St. Mary's City in Maryland, and in the vicinity of Yorktown, Virginia. In the process of classifying these specimens, I discovered several new species and subspecies of mollusks, which are the subject of this paper.

ACKNOWLEDGMENTS

The author wishes to express his sincere thanks and appreciation to Dr. William T. Clench and Dr. Ruth D. Turner, Museum of Comparative Zoology, Harvard University, for critically reading this manuscript and to Mr. Druid Wilson, United States Geological Survey, Washington, D.C. for comparing newly described fauna.

The holotypes and some paratypes are deposited in the United States National Museum.

EXPLANATION OF PLATE 4

FIG. *1*—*Turritella calvertensis*, n. sp. Maximum extrapolated length of the shell thus far observed about 60 mm.; width of last whorl 18 mm.

2—*Turritella calvertensis marylandica*, n. subsp. Maximum extrapolated length of the shell about 55 mm.; width of last whorl 14 mm.

3—*Turritella calvertensis plumpointensis*, n. subsp. Maximum extrapolated length of the shell about 35 mm.; width of last whorl 11 mm.

4—*Turritella indenta chesapeakensis*, n. subsp. Maximum extrapolated length of the shell about 35 mm.; width of last whorl 13 mm.

5—*Turritella variabilis chancellorensis*, n. subsp. Length of the shell about 25 mm.; width of last whorl 6 mm.

SYSTEMATIC DESCRIPTIONS

Class GASTROPODA

Order MESOGASTROPODA

Family TURRITELLIDAE

Genus TURRITELLA Lamarck 1799

TURRITELLA CALVERTENSIS, n. sp.

Pl. 4, fig. 1

Description.—Shell turreted, possessing about 15, but only 6 whorls preserved. Each of the postnuclear whorls widest at its base and therefore overhanging the deep suture below it; the base of each whorls flat or even slightly concave. Each of these whorls has a distinct keel along its base and a flat, inconspicuous rib located in the upper part of the whorls beneath the suture. The whorls nearly straight sided above the keel and, in the upper part, near the flat rib, a little concave. Surface of the whorls covered by rugose, spiral threads, some distinct and the others between them very fine. The spiral threads are intersected by distinct axial growth lines, forming a delicate reticulate sculpture on the shell.

The maximum extrapolated length of the shell thus far observed is about 60 mm. with a diameter of 18 mm. for the last whorl.

Remarks.—This species differs from *T. indenta* Conrad by a) overhanging structure of the whorls, b) a narrower sutures between the whorls, c) a distinct keel at the base of the whorls and only a flat rib in some distance beneath a deep and narrow suture, and d) only a slightly concave surface of the whorls below the upper rib.

The upper rib of *T. indenta* is located near the wide and deep suture, and the surface of the whorls is much more concave than in *T. calvertensis.*

Holotype: U.S.N.M. 563323; 1 paratype: U.S.N.M. 563324.

Type locality.—Turritella calvertensis occurs at Plum Point, Calvert County, Maryland. This species is not as abundant as *T. indenta,* and therefore, was overlooked earlier, although specimens from the Miocene strata at this locality have been collected and described for more than a century.

Range.—T. calvertensis is known only from grayish-green sand containing some clay of the Calvert formation at Plum Point, which corresponds to zone 10 of G. B. Shattuck.

TURRITELLA CALVERTENSIS MARYLANDICA, n.subsp.

Pl. 4, fig. 2

Description.—Shell turreted with 13 (only 10 preserved) nearly straight sided whorls in their lower, and slightly concave in their upper part; succeeding whorls slightly inset beneath the previous whorl. Keel sharp on early postnuclear whorls but becoming somewhat rounded on later whorls. The upper rib of the whorls flat and inconspicuous. Surface of the whorls covered by very delicate, rugose, spiral threads, intersected by distinct axial growth lines, pointing backward in the central parts of the whorls.

The maximum extrapolated length of the shell is about 55 mm. and width of 14 mm. for the last whorl.

Remarks.—This subspecies differs from the typical *T. calvertensis* in having the whorls less deeply inset and that the keel at the base of the last two whorls are more rounded than in the typical form.

Holotype: U.S.N.M. 563325.

Type locality.—Turritella calvertensis marylandica occurs at Plum Point, Calvert County, Maryland.

Range.—This subspecies is known from grayish-green sand containing some clay of the Calvert formation at Plum Point, which corresponds to zone 10 of G. B. Shattuck.

TURRITELLA CALVERTENSIS PLUMPOINTENSIS, n. subsp.

Pl. 4, fig. 3

Description.—Shell turreted with about 14 (only 8 preserved) whorls. Each of the postnuclear whorls has a distinct keel above the suture which it overhangs, and a flat rib in the upper part of the whorls below the suture. Just above the keel there is a prominent spiral ridge, separated from the basal keel by four very fine, rugose, spiral threads. Similar threads cover also the gentle concave surface of the whorls between the ridge and the rib below the suture. The spiral ridge and threads are intersected by delicate growth lines.

The maximum extrapolated length of the shell is about 35 mm. and width of 11 mm. for the last whorl.

Remarks.—This subspecies differs from typical *T. calvertensis* by a prominent spiral

ridge parallel to the basal keel and more delicate growth lines.

Holotype: U.S.N.M. 563326.

Type locality.—Turritella calvertensis plumpointensis occurs at Plum Point, Calvert County, Maryland.

Range.—This subspecies is known from grayish-green sand containing some clay of the Calvert formation at Plum Point, which corresponds to zone 10 of G. B. Shattuck.

TURRITELLA INDENTA CHESAPEAKENSIS, n. subsp.
Pl. 4, fig. 4

Description.—Shell possessing about 13 (but only 7 preserved) whorls, each with two distinct keels located near the deep sutures. Surface of the whorls strongly concave between the keels, bearing two spiral ridges; the ridge located near the lower keel more distinct than the upper one. Entire surface of the whorls covered by very delicate, rugose, spiral threads, intersected by axial growth lines. Aperture is subquadrate.

The maximum extrapolated length of the shell is about 35 mm. with width of 13 mm. for the last whorl.

Remarks.—This subspecies differs from *T. indenta* by having a) more concave surface of the whorls between the keels, b) two spiral ridges, one of which is located near the keels of each whorl; *T. indenta* possesses only one such ridge running along the keel at the base of the whorls.

Holotype: U.S.N.M. 563327.

Type locality.—Turritella indenta chesapeakensis occurs at Plum Point, Calvert County, Maryland.

Range.—This subspecies is known from grayish-green sand containing some clay of the Calvert formation at Plum Point, which corresponds to zone 10 of G. B. Shattuck.

TURRITELLA VARIABILIS CHANCELLORENSIS, n. subsp.
Pl. 4, fig. 5

Description.—Shell elongated, tapering gradually, with 11 whorls. Two spiral ridges, equally spaced, with the space between the two spiral ridges twice the width of the distance from the ridge to sutures. The first nuclear whorl turned to the side. Shell covered with very delicate spiral threads intersected with delicate growth lines.

The length of the shell is about 25 mm. and width 6 mm. for the last whorl.

Remarks.—This subspecies differs from *T. variabilis* by absence of additional spiral ridges on the middle, concave surface of the whorls, while *T. variabilis* possesses one indistinct spiral ridge in the middle part of the whorls, between the other ridges. *T. variabilis var. comberlandia* has two spiral ridges, each separated from the other by the same distance as its distance from the suture; therefore, they divide each whorl into three parallel, equally wide concave zones. The distance between two ridges on the described subspecies is twice as wide as the distance between ridges and the sutures.

Holotype: U.S.N.M. 563328; 6 paratypes: U.S.N.M. 563329.

Type locality.—Turritella variabilis chancellorensis occurs at St. Mary's City, Chancellor Point, St. Mary's County, Maryland, and at Marlboro, Cumberland County, New Jersey.

Range.—This subspecies is known from greenish-blue sandy clays of the St. Mary's formation in Maryland and from the greenish-blue sandy marls of the Kirkwood formation in New Jersey.

Class PELECYPODA
Order TELEODESMACEA
Family CARDIIDAE
Genus CERASTODERMA Poli 1795
CERASTODERMA CHANCELLORENSIS, n. sp.
Pl. 3, figs. 3,4

Description.—Shell subovate, inequilateral elongated posteriorly where it is obliquely truncated, the beak is placed anteriorly. Two cardinal teeth, the anterior one very thick, and the other, located posteriorly, thin. The deep socket between the cardinal teeth triangular in shape; the anterior lateral tooth larger than the posterior. Ligamental groove located posteriorly to the beak, short. Impressions of the anterior and posterior muscle scars shallow. Because the entire shell is very thin, the radial ribs and the furrows which form the exterior sculpture of the shell are marked on the interior surface, especially along the ventral margin below the palial line.

External sculpture of the shell formed by wide and flat radial ribs, 43 to 46 in number, separated by very narrow interradial furrows. Ten of the ribs located on the posterior obliquely truncated side of the shell and the other 33 to 36 ribs on the convex surface of the shell. In addition to the radial ribs and the furrows, the surface of the shell is also ornamented by fine, rugose, concentric growth lines.

The height of the shell is 22 mm. and the length 23 mm.

Remarks.—This species differs from *C. laqueatum* Conrad mainly in number and shape of radial ribs and interradial furrows, *C. laqueatum* possesses 28 to 33 radial ribs, rounded in cross-section and separated by interradial furrows of the same width as the ribs. *C. chancellorensis* possesses 43 to 46 wide and flat radial ribs, separated by very narrow interradial furrows.

Holotype: (double valves)—U.S.N.M. 563330; 10 paratypes: U.S.N.M. 563331.

Type locality.—Cerastoderma chancellorensis occurs at St. Mary's City, Chancellor Point, St. Mary's County, Maryland.

Range.—This species is known from the greenish-blue sandy clays of the St. Mary's formation in Maryland.

REFERENCES

ABBOT, R. T., 1955, American seashells: D. Van Nostrand Company, Inc., New York.

GARDNER, JULIA, 1924, Coastal plain and European Miocene and Pliocene mollusks: Bull. Geol. Soc. America, v. 35, p. 857–866.

——, 1926, The molluscan fauna of the Alum Bluff group of Florida: U. S. Geol. Survey, Prof. Paper 142-A.

——, 1943, Mollusca from the Miocene and Lower Pliocene of Virginia and North Carolina. Part 1, Pelecypoda: U. S. Geol. Survey, Prof. Paper 199-A.

RICHARDS, H. G., & HARBISON, A., 1942, Miocene invertebrate fauna of New Jersey: Proc. Acad. Nat. Sci. Phila., v. 94, p. 203–204.

SCHOONOVER, L., 1941, A stratigraphic study of the mollusks of the Calvert and Choptank formations of southern Maryland: Bull. Am. Paleontology, v. 25, no. 94 B.

SHATTUCK, G. B., 1904, Geological and paleontological relations of the Miocene deposits of Maryland: Maryland Geol. Survey, Miocene Volume.

WHITFIELD, R. P., 1894, Mollusca and crustacea of the Miocene formations of New Jersey: U. S. Geol. Survey, Mon. 24.

MANUSCRIPT RECEIVED SEPTEMBER 6, 1958.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 33–49, PLS. 5, 6, 3 TEXT-FIGS., JANUARY 1959

SCOLECODONTS FROM CENTRAL MISSOURI[1]

ROBERT K. SYLVESTER
Texas Company, New Orleans, Louisiana

ABSTRACT—Twenty-seven species of scolecodonts, seven of which are new, are described from the Upper Devonian Snyder Creek and the Lower Mississippian Chouteau formations of central Missouri. The schematic arrangement of the fossil groups of a nearly complete jaw apparatus illustrates its similarity to the recent annelid counterparts. Every major type of maxillary position is figured and described, and a standardized system of terminology is presented. Although no genus of scolecodonts is confined to one geologic period, Ordovician, Silurian, Devonian, and Mississippian groups can be differentiated on the basis of specific characters. The stratigraphic ranges of seven genera and ten species have been extended into the Mississippian as a result of this investigation.

INTRODUCTION

SCOLECODONTS are the fossil jaws of the annelid worms and have generally been regarded as paleontological curiosities. This has been due in part to their commonly minute size and their general paucity in the fossil record. There is, moreover, a prevailing belief among geologists and paleontologists that scolecodonts have little or no stratigraphical value. The common observation that the variation between scolecodonts and the jaws of the recent annelids is little more than the variation between members of closely related living genera has discouraged many workers. The objection is raised that these fossils all differ from one another and therefore defy classification—regardless of the fact that work during the last twenty-five years proves the contrary.

This approach to the study of annelid jaws is unfortunate for it has resulted in a marked departure from systematics whenever the study of scolecodonts is attempted. This is evident by the many conflicting ideas of classification, terminology, and morphology described in recent publications.

Although the record of worms in the form of trails and burrows extends into the Pre-Cambrian, it is not until the Ordovician that annelid jaws are preserved. There is a sporadic occurrence of scolecodonts from the Ordovician to the present, but they are more abundant in the Ordovician, Silurian, and Devonian with seemingly their greatest development during Middle and Upper Devonian time.

The scolecodonts described in this paper were collected from two distinct zones. The most productive fauna was recovered from the uppermost sandy facies in the Snyder Creek formation (Upper Devonian) at the Auxvasse quarry, SE ¼ sec. 34, T. 49 N., R. 9 W., Callaway County, Missouri. Jaws of Lower Mississippian age were also recovered at the Auxvasse quarry locality from a sandy black shale at the base of the Chouteau formation. A similar occurrence of Lower Mississippian scolecodonts is to be found approximately 2½ miles northwest of Brown's Station, about fifty yards upstream from the junction of two small unnamed creeks, NW ¼ NW¼ NW ¼ sec. 33, T. 50 N., R. 12 W., Boone County, Missouri. Here the scolecodonts were collected from thin shale partings in the basal members of the Chouteau formation.

The considerable variety and abundance of these fossils in the formations described above, from which scolecodonts have not been reported previously, suggests the need for a reevaluation of this group as stratigraphic determinants. Towards this end there is presented in the subsequent paragraphs a system of taxonomic and morphologic procedure.

ACKNOWLEDGMENTS

I would like to express my appreciation to M. G. Mehl, Professor of geology at the University of Missouri, who suggested the problem and under whose guidance this

[1] Submitted in partial fulfillment of the requirements for the degree of Master of Arts in the Graduate school of the University of Missouri, Columbia, Missouri, January 1957.

study was carried out. Professor Mehl's many helpful comments and criticisms in regard to the manuscript and illustrations were invaluable, and without his aid this paper would not have been completed. I am also grateful to the Department of Geology at the University of Missouri for the use of their research facilities and photographic equipment. Finally, I wish to thank all my fellow workers at the University from whom I received many helpful suggestions.

MORPHOLOGY

The morphology of the scolecodonts has not been studied in a systematic manner that has resulted in general agreement. Croneis & Scott (1933, p. 207) and Croneis (1941, p. 1246) proposed a terminology for the morphological features of scolecodonts, which generally has been ignored by subsequent workers. Only a few of their terms have been adopted by others, and none of their new proposals has been used in the ensuing literature.

A small minority of the morphological features listed in the present paper have been defined previously as such. Some workers have used the same term with different meanings and others have used different terms with the same meaning. I have found it necessary to define or re-define certain of these terms—all of which have been extracted from a scattered literature. This descriptive terminology, most of which is illustrated in text-figures 1 and 2, is presented alphabetically in the following glossary:

ANTERIOR—in general, the direction of the free end of the jaws when in articulation. The hook or fang is always anterior; in most forms the anterior end is opposite that occupied by the fossa. The beveled portion of mandibles also is anterior.

BASAL PLATE—a small unpaired plate, located on the upper surface at the base of the right forceps; nearly always associated with articulated jaw apparatuses.

BIGHT—a deep curve, commonly associated with the shank.

CARRIERS—two slender, posterior plates at the base of and supporting the forceps (Treadwell, 1921).

DENTAL PLATES—maxilla II; a generally denticulate asymmetrical pair of jaws situated ventrally and slightly anterior to the forceps (Lange, 1949).

DENTARY—the posterior denticulate portion of the jaw (Croneis, 1941).

DENTICLES—small, cone-shaped, spine-like, or blunt teeth occupying the inner margin of the jaw.

DEPTH—(see width)—the depth is measured at right angles to both the width and length; it is the vertical dimension perpendicular to the denticulate edge or inner margin.

FANG—the first denticle, at the anterior end, larger than the others and commonly hooked.

FLANGE—a projecting rim or ridge, commonly developed on the inner side or near the posterior end. (In some genera a flange occurs on both inner and outer sides.)

FORCEPS—maxilla I; a pair of toothed or edentulous jaws, united with and supported by a basal pair of carriers (Treadwell, 1921).

FOSSA—a distinct opening for muscle attachment on the upper side of the jaw (Eller, 1938).

FRONTAL PLATE—the terminal beveled portion at the anterior end of a mandible.

HOOK—the prominent recurved anterior portion of a jaw, usually associated with the maxilla I (Eller, 1934).

INNER MARGIN—the denticulate side or face of the jaw; the side towards which the anterior tooth or hook is curved. In certain genera, the inner margin may be on the under side.

JAW—an isolated plate, generally carrying a series of denticles on the inner margin. However, some consist of a single denticle (after Eller, 1934).

LENGTH—the measurement in an anterior-posterior direction; the distance measured between the anterior and posterior extremities.

MANDIBLES—a ventral pair of elongate shafts generally fused along the median line and each having a terminal beveled portion on the anterior end (Treadwell, 1921).

MAXILLA—a single jaw. In the jaw apparatus the jaws generally are found in pairs which are designated as maxillae I, II, III, IV, etc., numbered from posterior to anterior (after Treadwell, 1921, and Eller, 1934).

OUTER MARGIN—the side opposite that

of the denticulation (see inner margin).

PARAGNATH—maxilla IV; a minute denticulate distal paired plate anterior to the tips of the forceps (Lange, 1949).

POSTERIOR—the direction opposite the anterior tooth or hook; the inclination of the denticles (when present) is generally towards the posterior end; the fossa is commonly situated at the posterior end.

SCOLECODONT—the fossil jaw of a polychaetous worm.

SHAFT—the posterior, elongate portion of a mandible (Treadwell, 1921).

SHANK—an extended portion of the anterior margin of the jaw (may also be associated with the posterior) (after Eller, 1934).

UNDER SIDE—the ventral part of the jaw opposite the attachment side.

UNPAIRED PIECE—maxilla III; a generally denticulate unpaired jaw located on the left side of the jaw apparatus at the anterior end of the left dental plate; not always present (Treadwell, 1921).

UPPER SIDE—the dorsal portion of the jaw; the side occupied by the fossa.

WIDTH—the measurement at right angles to the length, generally between the extremities of the inner and outer margins.

The arrangement of the jaws in the mouth of the ancient worms is based on the associations in the mouth of the recent representatives. The typical annelid jaw apparatus, which is divided into two distinct parts, is illustrated diagrammatically in text-figure 1. The ventral part consists of a pair of mandibles, generally fused along the median line with only their anterior border protruded through the mouth. Each mandible has an elongate posterior shaft with a terminal beveled plate at the anterior end.

The other part of the jaw apparatus comprises the dorsal buccal armature which consists of a complex of maxillary plates. These are generally paired left and right and consist of many distinctive forms, which as fossils are most commonly found as detached isolated units. The dorsal system is composed of a posterior pair of carriers which support the forceps immediately to the anterior. Beneath the forceps, but still a part of upper jaw, are a pair of dental plates. These are followed anteriorly by one or more pairs of auxillary plates, an unpaired piece (not always present) located near the anterior end of the left dental plate; and the paragnaths or distal paired plates, located just beyond the tips of the forceps. In addition, a small basal plate, of uncertain relationship and known only from association with articulate jaw apparatuses, may be present on the upper side at the base of the right forceps. The forceps, dental plates, unpaired piece, and paragnaths are numbered respectively from posterior to anterior as maxilla I, II, III, IV, etc. (see text-fig. 1*c*). Among the recent polychaetes, many do not possess all these jaws. Some have only the forceps as their basic maxillary unit whereas in others the dental plates, unpaired piece, and paragnaths may or may not be present.

TAXONOMY

More often than not the jaws of fossil annelids are detached and scattered throughout the sediments in a haphazard manner. This has presented the greatest difficulty in the erection of a systematic classification and has been pointed out by nearly every writer on the subject.

Out of this confusion has arisen the practice, introduced by Ehlers in 1868, of assigning to the individual scolecodonts generic names derived from those of similar recent forms, as for example *Arabellites* from *Arabella*, *Eunicites* from *Eunice*, and *Leodicites* from *Leodice*. This method of deriving names for the fossil forms has been unfortunate for it is probable that several specific, possibly even generic names have been coined for different detached jaws that may belong to the same individual. On the other hand, isolated scolecodonts have been assigned to certain genera because of their similarity to a single maxilla of the modern form. In reality, however, they may be common to many different individuals.

The weakness in this system of classifying individual jaws according to their similarity to recent forms is obvious if one takes into consideration that only the complete jaw apparatus, preserved in its natural position, provides the necessary elements for identification. Although several complete fossil maxillary apparatuses have been described, such occurrences are rare. The number and arrangement of the maxillae in the jaw ap-

paratus of such a find furnishes a valuable criterion for family determination, and the shape of the individual plates within the assemblage affords a convenient tool for generic and specific association. Obviously, it is impossible to associate any detached jaw, as commonly found in the sediments, with any of the recent family, generic or specific groups. For this reason, the genera and species described in this paper have not been separated into families as has been advocated by some writers.

As the study of scolecodonts now stands, the majority of them have been named for the entire worm and not as a distinctive part of the worm. As a result, none of the genera of scolecodonts is characteristic of any one period of geologic time. If scolecodonts are to be used as stratigraphic indicators, they need only to be grouped and recognized as distinct individuals characteristic of a certain span of geologic time. It is recommended that a separate taxonomic category be utilized for the isolated or detached jaws, such as the parataxa grouping outlined by Moore & Sylvester-Bradley (1956). Under this proposal the individual scolecodonts would be assigned generic names independent of the entire worm designation, and complete articulate jaw apparatuses would be named as a whole animal taxa assigning a name exclusive and independent of the isolated or detached jaw.

Reconstructed Jaw Apparatus

Six species of scolecodonts from the Snyder Creek formation have been arranged schematically in text-fig. 3 to represent what is considered the complete maxillary apparatus of a Devonian worm. These six species occupy maxillary positions as follows: Maxilla I, left and right—*Nereidavus gigan-teus*, n. sp.; maxilla II, left—*Leodicites varie-dentatus* Eller; maxilla II, right—*Ildraites howelli* Eller; maxilla III—*Leodicites im-parilis*, n. sp.; maxilla IV, left—*Eunicites paranaensis* (Lange); maxilla IV, right—*Eunicites placidus* Stauffer.

It will be noticed that text-fig. 3 is a replica of the schematic diagram, text-fig. 1*c*. The mandibles and carriers could be respectively represented by *Diopatraites aversus* Eller (Pl. 5, figs. 9–12) and *Marphysaites liratus*, n. sp. (Pl. 6, figs. 19,20), but due to size relationships and the broken nature of these specimens I am not certain of their affinity.

No name has been assigned to this reconstructed assemblage since the zoological relationship and arrangement of the component jaws are purely speculative. It is interesting to note that this "jaw apparatus," supposedly from the mouth of one kind of individual, is composed of four different genera of scolecodonts. Should such a complete assemblage be found, the worm would receive a taxonomic name, and the individual parts would retain their parataxonomic designations.

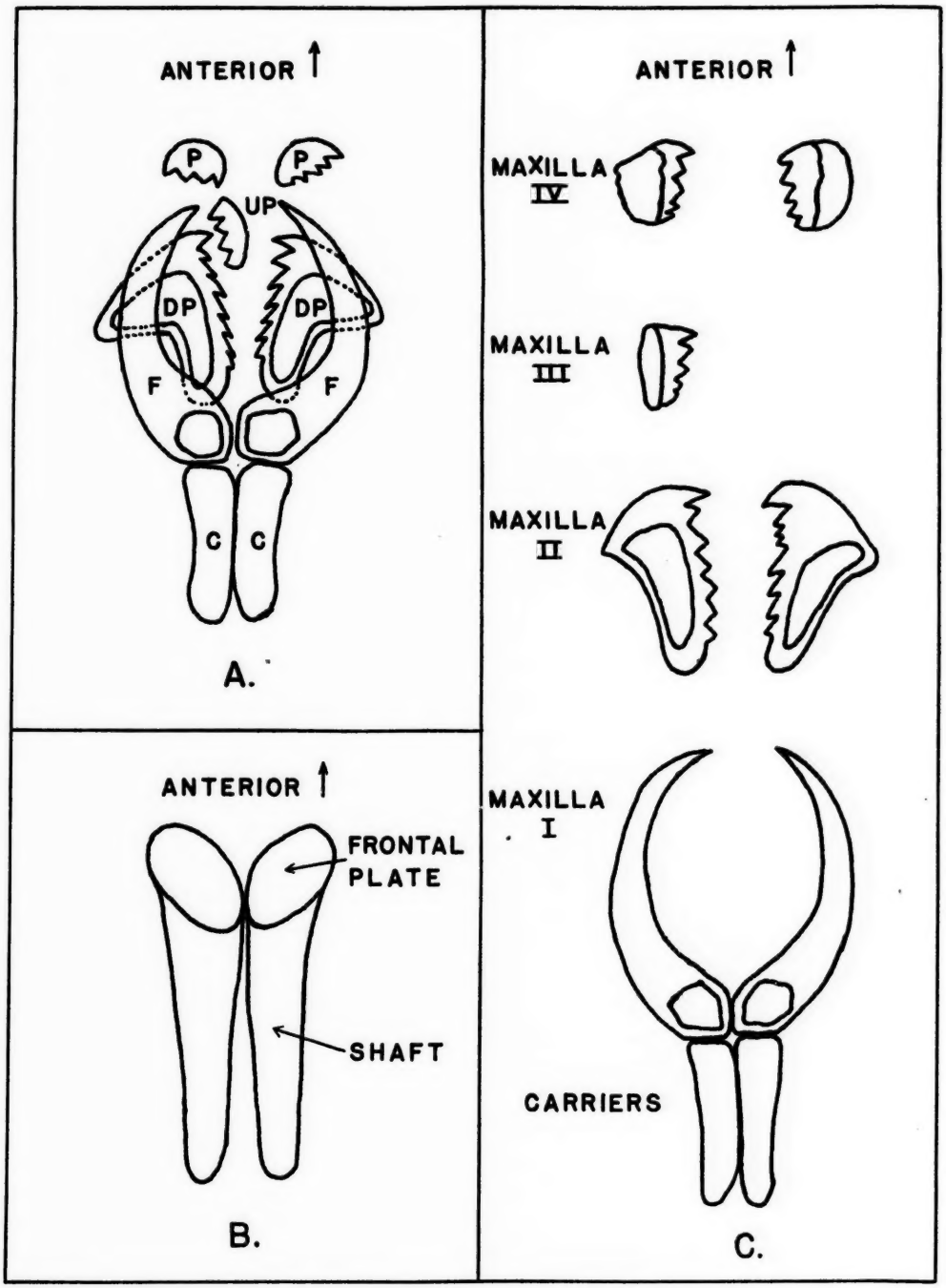
Conclusions

1. It is not possible to determine the relationship of detached scolecodonts to the modern genera with which they are compared.

2. A neontologic comparison is profitable only when the complete articulate maxillary apparatus to which the scolecodonts belong is known. A comparison based on the schematic reconstruction of the jaw apparatus of a Devonian worm, as outlined above, shows a striking similarity to the jaw parts of many recent polychaetes, especially to the Family Eunicidae.

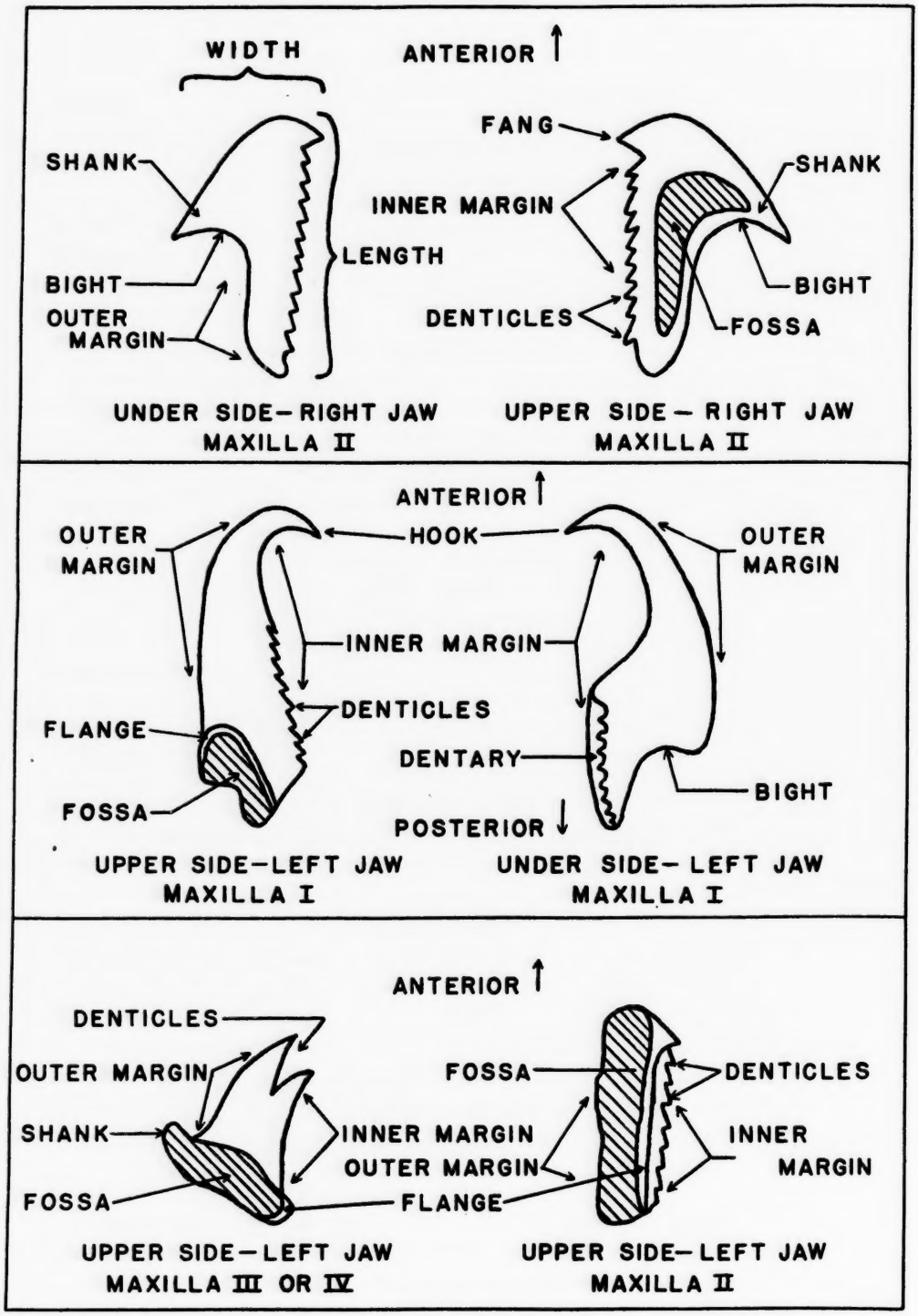
3. The stratigraphic ranges of many scolecodonts in the Snyder Creek-Chouteau fauna are herein defined or re-defined. Five species, *Eunicites scolatus*, n. sp., *E.* sp. indet., *Diopatraites ?* sp. indet. *A*, *D.* sp. indet. *B*, and *Paleoenonites dubious*, n. sp., are characteristic of the Mississippian. The genera, *Arabellites*, *Diopatraites*, *Leodicites*, *Lumbriconereites*, *Paleoenonites*, and *Stavrocephalites*, heretofore listed from the Ordovician, Silurian, and Devonian, are extended into the Mississippian. The species, *Arabellites comis* Eller, *A. cultriformis* Stauffer, *A. falciformis* Stauffer, *A. hamiltonensis* (Stauffer), *Eunicites conus* (Eller), *E. paranaensis* (Lange), *Leodicites variedentatus* Eller, *Staurocephalites aequilateralis* Eller, and *Ungulites agglomeratus* Eller, previously confined to the Devonian, are extended into the Mississippian.

4. The scolecodonts recovered from the Upper Devonian Snyder Creek formation are similar to those which occur in the Lower Mississippian Chouteau. For the



TEXT-FIG. *1*—Jaw apparatus of the annelid (modified after Treadwell, 1921)

A. Dorsal buccal armature, upper side; C, carrier; F, forceps, maxilla I; DP, dental plate, maxilla II; UP, unpaired piece, maxilla III; P, paragnath, maxilla IV.
B. Mandibles, upper side, ventral to buccal armature.
C. Schematic representation of buccal armature, upper side.



TEXT-FIG. 2—Scolecodont morphological features and terminology.

TEXT-FIG. *3*—Schematic arrangement of annelid jaw apparatus. *1,2*, maxilla I, forceps; *Nereidavus giganteus*, n. sp., left and right jaws, upper side, ×15. *3,4*, maxilla II, dental plates: *3*, *Leodicites variedentatus* Eller, left jaw, upper side, *4*, *Ildraites howelli* Eller, right jaw, upper side; ×15. *5*, maxilla III, unpaired piece; *Leodicites imparilis*, n. sp., left jaw, lateral view, ×30. *6,7*, maxilla IV, paragnaths; *6*, *Eunicites placidus* Stauffer, right jaw, upper side; *7*, *Eunicites paranaensis* (Lange), left jaw, upper side, ×30. Specimens in figures *5* and *3* were unconventionally lighted from the upper right in order to emphasize the inner margin. Due to the difficulties of whitening and photographing the specimens, the figures have been retouched where necessary to elucidate their correct outlines and distinguishing characteristics.

most part, they differ only in that many scolecodonts from the Snyder Creek formation are not present in the fauna collected from the Chouteau. Thus, on the basis of scolecodonts alone it is not presently possible to distinguish between the Devonian and Mississippian sediments. On the other hand, many Ordovician and Silurian species appear to be quite dissimilar to the forms described in this paper. It seems reasonable then, to conclude that scolecodonts may be utilized to some extent to differentiate between the Ordovician, Silurian, Devonian, and Mississippian.

5. At best, the value of scolecodonts as stratigraphic indicators is limited. Indeed, most genera range from the Ordovician, and it is necessary to resort to specific characteristics when attempting a stratigraphic interpretation. At present, the stratigraphic significance of scolecodonts is confined to the Middle Paleozoic sediments.

DEPOSITORY OF SPECIMENS

All the specimens described in this paper have been placed in the Paleontological collections of the University of Missouri and are kept and catalogued in the Department of Geology. The figured specimens were assigned numbers preceded by SCO, which is the symbol for scolecodonts in the University of Missouri collections.

SYSTEMATIC DESCRIPTIONS

Phylum ANNELIDA
Class POLYCHAETA
Order ERRANTIA
Genus ARABELLITES Hinde, 1879

Diagnosis.—Jaws of maxilla I and II; the former consisting of elongate jaws with a prominent anterior hook or fang, denticulate inner margin or dentary, and a sharply to obliquely truncate posterior end; the latter are characterized by small sickle-shaped jaws without an anterior fang and with a deep bight and prominent shank.

Remarks.—It is necessary to give Hinde's original description a generous interpreta-

tion due to the general nature of the statement. In my opinion, the "Jaws subquadrate in form, with a straight upper edge of small teeth" (Hinde, 1879, p. 377) of Hinde's third division are paragnaths and should be assigned to the genus *Eunicites* for the best paleontological reference.

Type species.—*Arabellites hamatus* Hinde.

ARABELLITES COMIS Eller
Maxilla I, pl. 5, figs. 1–4

Arabellites comis ELLER, 1938, p. 277, pl. 28, fig. 9.
Arabellites comis STAUFFER, 1939, p. 501, pl. 58, figs. 21,22,28.

Diagnosis.—Small, subtriangular jaws of maxilla I with a denticulate inner margin and a prominent fang; short spur-like projections extending posteriorly from the inner and outer margins of the base; and an obliquely truncate posterior end.

Hypotype.—Univ. Mo., SCO 1-1.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.; Chouteau fm., near Brown's Station, Boone County, Mo.

ARABELLITES CULTRIFORMIS Stauffer
Maxilla II, pl. 5, figs. 7,8

Arabellites cultriformis STAUFFER, 1939, p. 502, pl. 58, figs. 9,10.

Diagnosis.—Small, sickle-shaped left jaws of maxilla II with two or three prominent anterior denticles followed by eight to ten denticles decreasing in size posteriorly.

Hypotype.—Univ. Mo., SCO 1–4.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.; Chouteau fm., near Brown's Station, Boone County, Mo.

ARABELLITES FALCIFORMIS Stauffer
Maxilla II, pl. 5, figs. 5,6

Arabellites falciformis STAUFFER, 1939, p. 502, pl. 58, figs. 13,15,16.

Diagnosis.—Small, sickle-shaped right jaws of maxilla II with two or three prominent anterior denticles followed by eight to ten denticles decreasing in size posteriorly.

Remarks.—It is evident that *Arabellites falciformis* and *A. cultriformis* are counterparts of one another—the former being the maxilla II, right jaw; and the latter the maxilla II, left jaw.

Hypotype.—Univ. Mo., SCO 2–1.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.; Chouteau fm., near Brown's Station, Boone County, Mo.

ARABELLITES HAMILTONENSIS (Stauffer)
Maxilla I, pl. 5, figs. 35–39

Protarabellites hamiltonensis STAUFFER, 1939, p. 509, pl. 57, figs. 22,23; pl. 58, figs. 35,36.
Arabellites hamiltonensis ELLER, 1941, p. 335, pl. 38, figs. 19,20.

Diagnosis.—Elongate, symmetrical pairs of maxilla I with a prominent offset hook and a dentary of seven to nine minute denticles along the posterior third of the inner margin; a large wide fossa occupies nearly two-thirds of the upper surface, and the posterior end is abruptly truncate.

Hypotypes.—Univ. Mo., SCO 2–3, 3–1.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.; Chouteau fm., near Brown's Station, Boone County, Mo.

Genus DIOPATRAITES Eller, 1938

Diagnosis.—Large mandibles, typically with a three-toothed frontal plate followed by a tapering shaft.

Remarks.—Many specimens which Eller includes in this genus do not exhibit the typical three-toothed frontal margin. He attributes this to the broken anterior ends which are quite common. Most specimens which I have collected are similarly broken and are placed in the genus *Diopatraites* in accordance with the precedence set by Eller.

Type species.—*Diopatraites conformis* Eller.

DIOPATRAITES AVERSUS Eller
Mandible, pl. 5, figs. 9–12

Diopatraites aversus ELLER, 1955, p. 371, pl. 26, figs. 18–20.

Diagnosis.—Mandibles with a large, heavy frontal plate, the posterior end of which turns away abruptly to nearly a forty-five degree angle and continues to an acute end. The shaft is short and triangular in cross-section and joins the frontal plate with a nearly straight margin.

Hypotype.—Univ. Mo., SCO 3–5.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.

DIOPATRAITES ? *sp. indet.* A
Mandible, pl. 5, figs. 13,14

Description.—The mandible is small with the upper surface of the large frontal plate finely pitted or granulose. The inner margin of the frontal plate is straight and the outer margin is curved so that the plate tapers to a blunt point. The under side of the frontal plate is marked by a distinct central ridge extending the length of the plate until it connects with the inner margin at the junction of the frontal plate and the shaft. The shaft is slightly longer than the frontal plate and both are set at nearly a forty-five degree angle with each other. The shaft turns away abruptly at the union with the anterior part of the jaw and continues into an acute end on the inner side. The upper and under sides of the shaft are smooth and flat. The outer margin of the shaft is straight whereas the inner margin is curved slightly towards the posterior end. The figured specimen measures 0.65 mm. in length.

Remarks.—The single specimen recovered does not exhibit the characteristic three-toothed anterior of the genus *Diopatraites* and is temporarily placed in this genus until more such forms are available for study.

Hypotype.—Univ. Mo., SCO, 4-2.

Occurrence.—Chouteau fm., near Brown's Station, Boone County, Mo.

DIOPATRAITES sp. indet. B
Mandible, pl. 5, figs. 15,16

Description.—The right mandible is small and exhibits the typical characteristics of the genus. The frontal plate is oval in outline and is marked by three small teeth on the anterior margin which decrease in size posteriorly. The entire under side of the mandible is slightly concave, and on this side the frontal plate and shaft appear as one piece. The upper surface of the frontal plate and shaft are distinctly separate on the upper side and join at an angle of about thirty degrees. The figured specimen measures 0.6 mm. in length.

Remarks.—Several specimens of this type were collected but most are broken in such a manner that specific determination is not possible.

Hypotype.—Univ. Mo., SCO, 4-3.

Occurrence.—Chouteau fm., near Brown's Station, Boone County, Mo.

Genus EUNICITES Ehlers, 1868

Diagnosis.—Small, subquadrate jaws of maxilla III? and IV with a denticulate inner margin; and jaws of maxilla V consisting of a more or less curved single denticle. A large fossa occupies most of the upper surface.

Remarks.—The original description of the genus *Eunicites* is inadequate since the entire worm is described and the jaws are mentioned only briefly. In my opinion, the genus *Eunicites* should be limited to maxillae IV and V and perhaps III for the best paleontological reference. The maxillae I and II, heretofore described as the genus *Eunicites*, should be referred to separate genera or to a separate genus.

Type species.—*Eunicites avitus* Ehlers.

EUNICITES CONUS (Eller)
Maxilla IV or V, pl. 5, figs. 19–22

Arabellites ? conus ELLER, 1938, p. 277, pl. 29, fig. 7.

Eunicites conus (ELLER) 1955, p. 360, pl. 24, figs. 24,25.

Diagnosis.—Small, straight, to slightly curved, cone-shaped jaws of Maxilla IV or V with a wide, projecting flange along the inner-anterior border of the fossa.

Revised description.—The jaw is small and consists of a single, cone-shaped, posteriorly directed denticle which may be either pointed or blunt. The anterior half of the inner margin of the fossa is projected into a flange which gradually widens toward the anterior end. The outer and posterior-outer margins are generally broken. A large fossa occupies almost two-thirds of the upper surface of the jaw. The figured specimens measure from 0.57 to 0.60 mm. in length and from 0.48 to 0.51 mm. in width.

Hypotype.—Univ. Mo., SCO, 4–5.

Occurrence.—Snyder Creek fm., Chouteau fm., Auxvasse quarry, Callaway County, Mo.

EUNICITES PARANAENSIS (Lange)
Maxilla IV, pl. 5, figs. 28,29; text-fig. 3–7

Paulinites paranaensis LANGE, 1947, left paragnath, p. 40, pl. 1, fig. 1; pl. 11, figs. 27–36.

Diagnosis.—Small, subquadrate, left jaws of maxilla IV with an inner margin of five to thirteen discrete denticles, the first of which is larger than the others. A small anteriorly directed beak exists at the median

part of the anterior margin. The inner-anterior edge of the fossa is thickened and forms another projecting beak on the upper side near the base of the first denticle.

Remarks.—This species has been described by Lange as the left paragnath from the jaw apparatus of *Paulinites paranaensis.* Since no generic or specific names were given the members of this jaw apparatus, I have taken the left paragnath out of the taxonomic genus *Paulinites* and placed it in its obvious parataxonomic generic association.

Hypotype.—Univ. Mo., SCO 5–2.

Occurrence.—Snyder Creek fm., Chouteau fm., Auxvasse quarry, Callaway County, Mo.

EUNICITES PLACIDUS Stauffer
Maxilla IV, pl. 5, figs. 30,31; text-fig. 3–6

Eunicites placidus STAUFFER, 1939, p. 506, pl. 58, fig. 1.
Paulinites paranensis LANGE, 1947, right paragnath, p. 39, pl. 1, fig. 1; pl. 11, figs. 13–26.

Diagnosis.—Small, subtriangular right jaws of maxilla IV with a small, anteriorly directed beak at the median part of the anterior margin. The inner margin has nine to sixteen closely arranged denticles, without a fang; the inner border of the fossa is thickened and forms another projecting beak on the upper side at the anterior third of the fossa margin.

Remarks.—*Eunicites placidus* differs from *E. paranaensis* chiefly in that the latter is a left jaw, more quadrate in shape, and has discrete denticles with a relatively large fang; whereas the former is a right jaw and has a larger number of closely arranged denticles without an anterior fang.

Hypotype.—Univ. Mo., SCO 5-5.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.

EUNICITES SCOLATUS, n. sp.
Maxilla IV or V, pl. 5, figs. 23,24

Diagnosis.—Small jaws of maxilla IV or V consisting of a single, sharp-pointed, thorn-like denticle tapering rapidly from the center of a wide base. A conspicuous flange is present along the inner-anterior border of the fossa.

Description.—The jaw is small and consists of a single, sharp-pointed, thorn-like denticle, tapering rapidly from the center of a wide base to an acute point. The denticle may be curved slightly towards the under side but exhibits little or no lateral curvature. The inner and outer margins of the denticle are marked by a faint ridge running the length of the tooth. The upper and under margins of the denticle are rounded. The posterior part of the jaw is sub-elliptical in shape, and a shallow fossa occupies two-thirds of the posterior base. A thick and conspicuous flange is present on the inner-anterior margin of the fossa. The figured specimen measures 0.5 mm. in length and 0.35 mm. in width.

Holotype.—Univ. Mo., SCO, 6-2.

Occurrence.—Chouteau fm., Auxvasse quarry, Callaway County, Mo.

EUNICITES sp. indet.
Maxilla IV or V, pl. 5, figs. 17,18

Remarks.—Only two specimens of this type were recovered. They bear a striking resemblance to *Eunicites absonus* Eller (1955). Both have the shape of a small, sharp-pointed hook and differ from *E. absonus* only in the nature of the posterior end and in the width of the jaw. It is possible that examination of more specimens of this type will reveal *E. sp. indet.* to be conspecific with *E. absonus.*

Hypotype.—Univ. Mo., SCO 6-4.

Occurrence.—Chouteau fm., near Brown's Station, Boone County, Mo.

Genus ILDRAITES Eller, 1936

Diagnosis.—Jaws of maxilla I with a prominent hook, denticulate inner margin or dentary and a sickle-shaped posterior margin with a deep crescent-shaped bight; jaws of maxilla II with a prominent fang, denticulate inner margin and a distinct shank extending posteriorly from the anterior end and forming a crescent-shaped bight along the outer margin.

Type species.—*Arabellites bipennis* Eller.

ILDRAITES HORRIDUS? Eller
Maxilla II, pl. 6, figs. 25,26

Ildraites horridus ELLER, 1949, p. 30, pl. VI, figs. 6–9.

Diagnosis.—Large, rudely triangular shaped, left and right jaws of maxilla II with

a distinctly large fang. The second denticle is not in the usual place but is separated from the fang by a deeply concave edentulous portion of the inner margin and is followed by a series of smaller denticles.

Remarks.—The single specimen recovered differs basically from the right jaw of *Ildraites horridus* only in size, the figured specimen being approximately one-half the size of Eller's species. It is conceivable that *Ildraites horridus?* represents an immature form.

Hypotype.—Univ. Mo., SCO, 6-5.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.

ILDRAITES HOWELLI Eller

Maxilla II, pl. 6, figs. 32–34; text-fig. 3–4

Ildraites howelli ELLER, 1941, p. 328, pl. 37, figs. 11,12,15,16.

Paulinites paranaensis LANGE, 1947, left dental plate, p. 36, pl. 10, figs. 13–24; pl. 14, figs. 6–9.

Diagnosis.—Subtriangular right jaws of maxilla II with a sigmoid anterior margin incurving into a medium-sized shank. Posterior to the fang, the inner margin bears two to eight intermediate denticles followed by seven to fourteen normal denticles. A thickened, conspicuous flange extends along the posterior half of the inner margin of the fossa.

Remarks.—*Arabellites priscus* Stauffer, 1939, is similar to *Ildraites howelli* and apparently differs only in the number of denticles. Since Stauffer's description is short and since he figures only one side of the specimen, it is not possible to be certain if *A. priscus* is conspecific with *I. howelli.*

Hypotype.—Univ. Mo., SCO 7-1.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.

Genus LEODICITES Eller, 1940

Diagnosis.—Triangular shaped, medium size jaws of maxillae II and III having a denticulate inner margin without a fang or primary denticle. The anterior margin is generally incurved to form a blunt or acute shank followed posteriorly by a bight along the outer margin. A large fossa occupies from half to nearly all the length of the jaw.

Type species.—*Leodicites variedentatus* Eller.

LEODICITES IMPARILIS, n. sp.

Maxilla III, pl. 5, figs. 25–27; text-fig. 3–5

Diagnosis.—Unpaired jaws of maxilla III with a sharply truncate anterior end and an inner margin with denticles extending the length of the jaw towards a blunt posterior end. The entire outer side is occupied by a deep triangular fossa.

Description.—The jaw is triangular shaped with a series of 8 to 11 triangular, sharp-pointed denticles extending the entire length of the jaw. The denticles are inclined towards the blunt posterior end. The inner margin is slightly arched and incurved, the greatest height and curvature being at the anterior end. The first two denticles are generally smaller than the others which decrease only slightly in size towards the posterior. The first denticle appears as a continuation of the anterior margin which is sharply truncate and extends into a short, pointed shank on the upper side. This is followed posteriorly by a shallow bight on the outer margin of the upper surface. A small protuberance or shank is also present at the junction of the anterior margin and the under side. The entire outer side is occupied by a deep triangular fossa which is surrounded by a thick rounded margin. A distinct furrow, presumably for attachment purposes, parallels the upper margin of the fossa. The upper side is concave, the under side convex. The jaw measures 0.8 mm. to 0.9 mm. in length and about 0.4 mm. in width.

Remarks.—*Leodicites imparilis* is similar to *Paulinites paranaensis* Lange, 1947, unpaired piece, but differs in the number and arrangement of the denticles, the curvature of the outer margin, and in the nature of the anterior shank.

Holotype.—Univ. Mo., SCO 7-3.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.

LEODICITES SCITULUS Eller

Maxilla II, pl. 5, fig. 40

Leodicites scitulus ELLER, 1941, p. 332, pl. 37, figs. 14,15.

Diagnosis.—Small jaws of maxilla II with an inner margin of about six denticles, the first of which is curved and followed by a larger second denticle. A shallow bight exists near the middle of the rounded anterior

margin and extends from the first denticle to a pointed, curved shank at the outer margin.

Hypotype.—Univ. Mo., SCO 7-5.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.

LEODICITES VARIEDENTATUS Eller

Maxilla II, pl. 6, figs. 39,40; text-fig. 3–3

Leodicites variedentatus ELLER, 1940, p. 13, pl. 7, figs. 1–4.
Leodicites reimanni ELLER, 1941, p. 333, pl. 37, figs. 10–13.
Paulinites paranaensis LANGE, 1947, right dental plate, p. 33, pl. 10, figs. 1–12; pl. 14, figs. 1–5.

Diagnosis.—Medium size left jaws of maxilla II with an inner margin of eleven to fifteen denticles. The first denticle is small and is often supplemented by a larger second or third denticle. The posterior end is blunt; the fossa is deep and extends for about two-thirds the length of the jaw.

Hypotype.—Univ. Mo., SCO 8-1.

Occurrence.—Snyder Creek fm., Chouteau fm., Auxvasse quarry, Callaway County, Mo.

Genus LUMBRICONEREITES Ehlers, 1868

Diagnosis.—Small to large, oblong, left and right jaws of maxillae I or II with a fang and denticulate inner margin located on the under side of the jaw. The outer-anterior margin extends laterally into a broad shank followed posteriorly by a shallow bight. The shank is not always developed on the left jaw. A deep and wide fossa occupies three-fourths of the outer and upper surfaces including the shank.

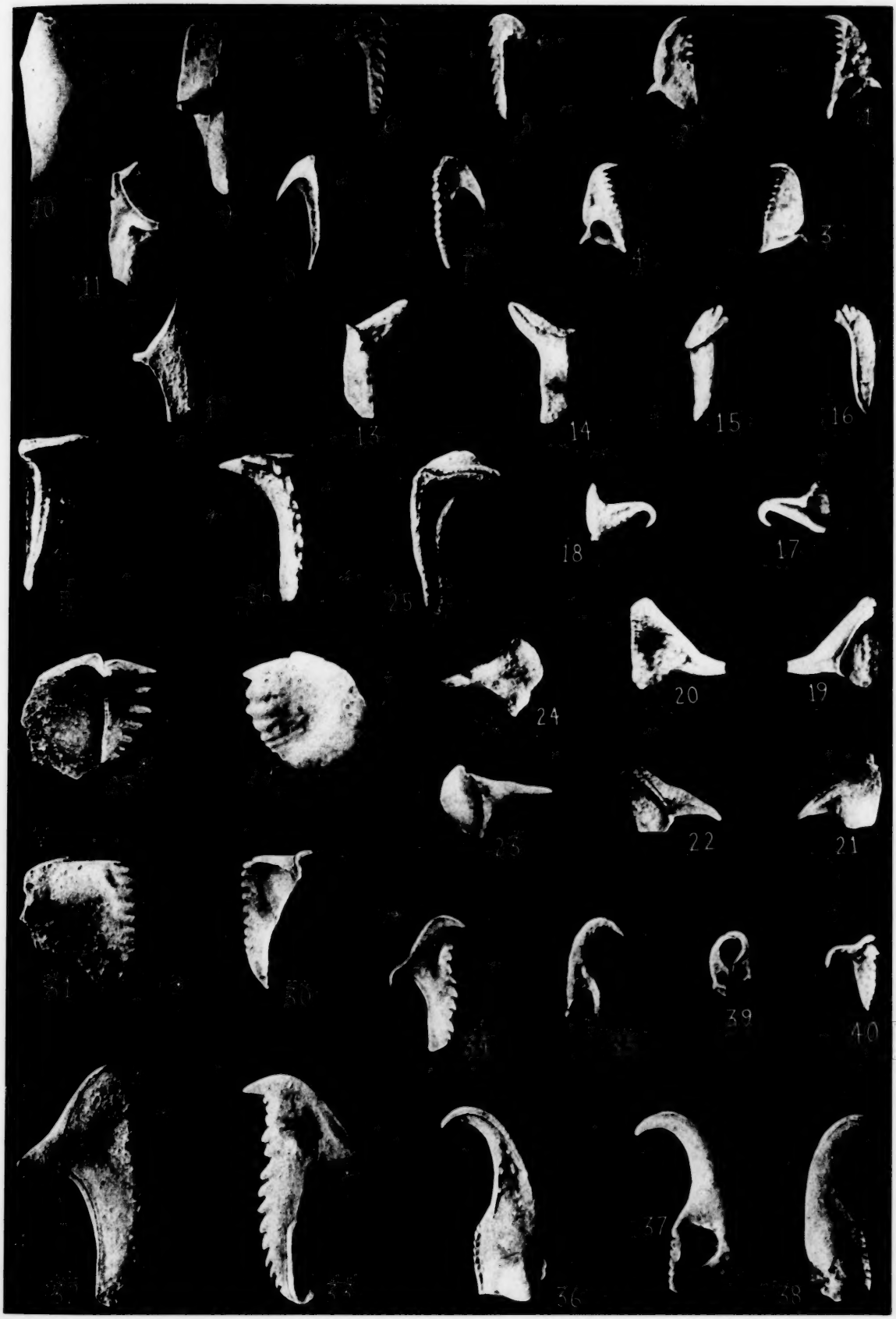
Type species.—*Lumbriconereites deperditus* Ehlers.

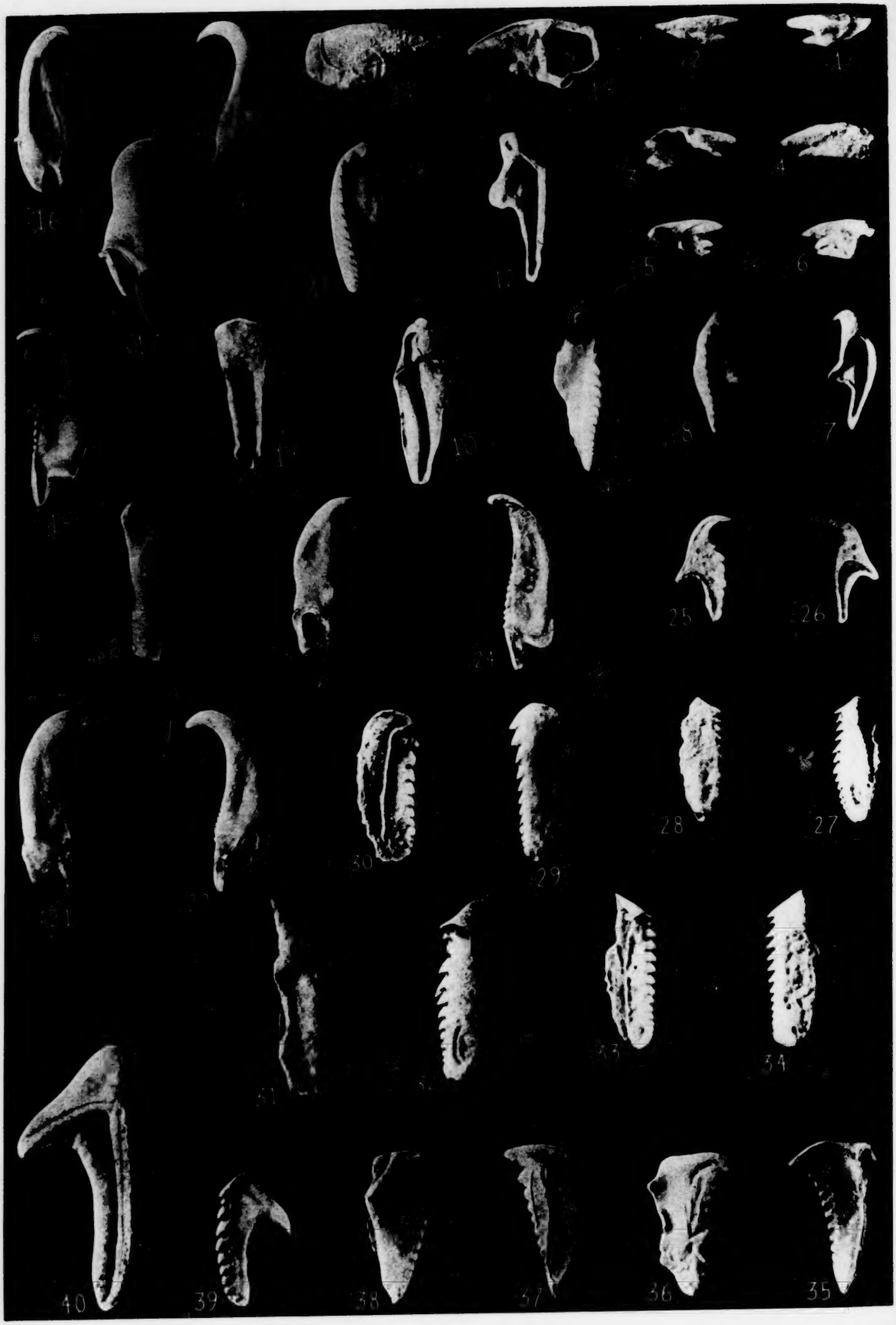
EXPLANATION OF PLATE 5

All figures ×30 unless otherwise noted.

FIGS. *1–4*—*Arabellites comis* Eller. Maxilla I; *1,2*, right jaw, upper and under sides; *3,4*, left jaw, under and upper sides; hypotype, UM SCO 1–1.
5,6—*Arabellites falciformis* Stauffer. Maxilla II; right jaw, upper and under sides, hypotype, UM SCO 2-1.
7,8—*Arabellites cultriformis* Stauffer. Maxilla II; left jaw, under and upper sides, hypotype, UM SCO 1–4.
9–12—*Diopatraites aversus* Eller. Mandible; *9,10*, right shaft, upper and under sides; *11,12*, left shaft, upper and under sides; hypotype, UM SCO 3–5, ×15.
13,14—*Diopatraites?* sp. indet. *A*. Mandible; right shaft, upper and under sides, figured specimen, UM SCO 4–2.
15,16—*Diopatraites* sp. indet. *B*. Mandible; right shaft, upper and under sides, figured specimen, UM SCO 4–3.
17,18—*Eunicites* sp. indet Maxilla IV or V; right jaw, upper and under sides, figured specimen, UM SCO 6–4.
19–22—*Eunicites conus* (Eller). Maxilla IV or V; *19,20*, right jaw, upper and under sides; *21,22*, left jaw, under and upper sides; hypotype, UM SCO 4–5.
23,24—*Eunicites scolatus*, n. sp. Maxilla IV or V; left jaw, upper and under sides, holotype, UM SCO 6–2.
25–27—*Leodicites imparilis*, n. sp. Maxilla III; *25,26*, left jaw, upper and under sides; *27*, left jaw, lateral view; holotype, UM SCO 7–3.
28,29—*Eunicites paranaensis* (Lange). Maxilla IV; left jaw, upper and under sides, hypotype, UM SCO 5–2.
30,31—*Eunicites placidus* Stauffer. Maxilla IV; right jaw, upper and under sides, hypotype, UM SCO 5–5.
32–34—*Ildraites howelli* Eller. Maxilla II; *32,33*, right jaw, under and upper sides; *34*, right jaw, under side ×15; hypotype, UM SCO 7–1.
35–39—*Arabellites hamiltonensis* (Stauffer). Maxilla I; *35,36*, left jaw, upper side ×15 and under side; *37,38*, right jaw, upper and under sides; *39*, right and left jaws in articulation; hypotype, UM SCO 2–3.
40—*Leodicites scitulus* Eller. Maxilla II; right jaw, under side, hypotype, UM SCO 7–5.

Due to the difficulties of whitening and photographing the specimens, many figures have been retouched where necessary to elucidate their correct outlines and distinguishing characteristics.


1
10
11
13
14
15
16
17
18
19
20
21
22
24
25
39
40
36
37
38


40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

LUMBRICONEREITES CONFORMIS, n. sp.
Maxilla II, pl. 6, figs. 7,8

Diagnosis.—Small, oblong jaws of maxilla II with a posteriorly hooked fang followed by about ten denticles. A shallow bight exists on the anterior side of a small, angular, pointed shank.

Description.—The jaw is wide at the mid-area and tapers gradually to a rounded anterior end and an acute posterior. The inner margin is curved at the anterior end and is marked by a series of about 10 to 12 blunt and conical, posteriorly inclined denticles. A relatively large fang appears as a continuation of the outer-anterior margin and is slightly hooked towards the posterior. The remaining denticles are small and decrease in size posteriorly. A small, angular, pointed shank is present along the median part of the outer margin. The angularity is emphasized by a small indentation or bight on the anterior side of the shank. A large fossa occupies the posterior three-fourths of the upper side, including the shank. The margins of the fossa are slightly thickened and rounded. The figured specimen in 0.57 mm. in length and 0.28 mm. in width at the mid-area.

Remarks.—Only a few specimens of this type were recovered. They bear a striking similarity to *Lumbriconereites linki* Eller, 1945, but differ in the curvature of the inner anterior margin, the position of the shank, and in the nature of the width of the jaw.

Holotype.—Univ. Mo., SCO 8-4.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.

LUMBRICONEREITES COOPERI Eller
Maxilla I, pl. 6, figs. 9–12

Lumbriconereites cooperi ELLER, 1938, p. 275, pl. XXVIII, fig. 1–8.

Diagnosis.—Asymmetrical right and left, large, oblong jaws of maxilla I with twelve to nineteen denticles along the inner margin and a large posteriorly curved fang. The shank of the right jaw is rounded and broadly triangular; the left jaw bears a slight suggestion of an indentation about the mid-point.

Hypotype.—Univ. Mo., SCO 9-1.

Occurrence.—Snyder Creek fm., Chouteau

EXPLANATION OF PLATE 6

All figures ×30 unless otherwise noted.

FIGS. *1–6—Ungulites spicatus*, n. sp. Maxilla IV or V; *1,2*, right jaw, upper and under sides; *3,5*, left jaw, upper side; *4,6*, left jaw, under side; holotype and paratype, UM SCO 13–3, 13–4.
7,8—Lumbriconereites conformis, n. sp. Maxilla II; right jaw, upper and under sides, holotype, UM SCO 8–4.
9–12—Lumbriconereites cooperi Eller. Maxilla I; *9,10*, left jaw, under and upper sides; *11,12*, right jaw, under and upper sides; hypotype, UM SCO 9–1, ×15.
13,14—Ungulites agglomeratus Eller. Maxilla III or IV; right jaw, upper and under sides, hypotype, UM SCO 13–2.
15–18—Nereidavus giganteus, n. sp. Maxilla I; *15,16*, right jaw, upper and under sides; *17,18*, left jaw, upper and under sides; holotype, UM SCO 10–1, ×15.
19,20—Marphysaites liratus, n. sp. Carrier; *19*, upper side; *20*, under side; holotype, UM SCO 9–5.
21–24—Nereidavus harbisonae Eller. Maxilla I; *21,22*, right jaw, under and upper sides; *23,24*, left jaw, upper and under sides; hypotype, UM SCO 11–2.
25,26—Ildraites horridus ? Eller. Maxilla II; right jaw, under and upper sides, hypotype, UM SCO 6–5.
27–30—Staurocephalites aequilateralis Eller. Maxilla II; *27,28*, right jaw, upper and under sides; *29,30*, left jaw, under and upper sides; hypotype, UM SCO 12–3.
31–34—Staurocephalites alterostris Eller. Maxilla II; *31,32*, right jaw, under and upper sides; *33,34*, left jaw, upper and under sides; hypotype, UM SCO 13–1.
35–38—Paleoenonites dubius, n. sp. Maxilla II; *35,36*, right jaw, upper and under sides; *37,38*, left jaw, under and upper sides; holotype, UM SCO 11–4.
39,40—Leodicites variedentatus Eller. Maxilla II; left jaw, under side (×15) and upper side; hypotype, UM SCO 8–1.

Due to the difficulties of whitening and photographing the specimens, it has been necessary to retouch many figures in order to elucidate their correct outlines and distinguishing characteristics.

fm., Auxvasse quarry, Callaway County, Mo.; Chouteau fm., near Brown's Station, Boone County, Mo.

Genus MARPHYSAITES Eller, 1945

Diagnosis.—Small, slender, elongate carriers with a wide anterior margin, tapering to a pointed or blunt posterior end.

Remarks.—Eller has described the genus *Marphysaites* as a mandible, but in the description of the genotype he mentions that it might be considered as a carrier. At the time, all paired carriers had had straight articulate inner margins. Since the inner margins of the genotype are somewhat curved, and articulate only at the anterior end, Eller listed them as mandibles. With the event of Lange's discovery (1947) of an articulate jaw apparatus illustrating carriers with curved, inarticulate inner margins, it is now thought that the genus *Marphysaites* would be better described as a carrier.

Type species.—*Marphysaites aptus* Eller.

MARPHYSAITES LIRATUS, n. sp.
Carrier, pl. 6, figs. 19,20

Diagnosis.—Small, slender, elongate carriers with a convex under surface. A distinct, wide, furrowed fossa, which diminishes towards the anterior end, occupies the upper surface.

Description.—The carriers are short and narrow. The well-rounded margin of the wide anterior end is straight or slightly curved. The inner and outer margins are rounded and in some specimens a slight flange is evident. The carriers taper gently from the wide anterior end to the broken posterior, and the lateral margins may be slightly incurved. The upper surface is concave and marked by a deep furrowed fossa occupying nearly the entire width of the plate. The fossa widens and diminishes into the width of the anterior end. The under side is highly convex. Specimens average 0.85 mm. in length but since all the specimens are broken at the posterior end the actual length is probably slightly greater than 1 mm. The width ranges from 0.3 mm. at the anterior end to about 0.15 mm. at the mid-length.

Holotype.—Univ. Mo., SCO 9-5.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.

Genus NEREIDAVUS Grinnell, 1877

Diagnosis.—Medium to large, elongate jaws of maxilla I with a distinct hook, blunt denticles, and an irregularly truncate posterior end.

Type species.—*Nereidavus varians* Grinnell.

NEREIDAVUS GIGANTEUS, n.sp.
Maxilla I, pl. 6, figs. 15–18; text-fig. 3—1,2

Diagnosis.—Elongate, asymmetrical pairs of maxilla I characterized by their large size and by a distinct knob or protuberance located on the outer margin near the anterior border of the fossa.

Description.—The jaws consist of a long and wide asymmetrical pair. The denticulation begins about one-quarter the distance from the anterior end on the inner margin and consists of a crenulate edge of 5 to 10 minute, posteriorly inclined, triangular-shaped, blunt denticles which continue to about the mid-point of the jaw. This crenulation grades into a series of 7 to 10 larger, posteriorly inclined, triangular-shaped, sharp denticles which increase in size for a short distance and then decrease again to a point about one-third the distance from the posterior end where the denticulation is terminated. A large, sharp anterior hook is strongly curved backward and inward, oblique to the plane of the inner margin. A distinct ridge runs from near the tip of the hook on the under side towards the posterior where it gradually diminishes along the outer margin about one-third the distance from the anterior end. The outer margin is relatively straight. The inner margin is slightly convex to the point where the hook begins, at which the former becomes highly concave. A distinct knob or protuberance extends outward from the anterior part of the fossa near the outer margin and appears as a continuation of the fossa margin. This protuberance is about 0.07 mm. in length. The left and right jaws differ fundamentally at the posterior end. The posterior end of the right jaw is irregularly truncate with a deep and wide fossa. The posterior of the left jaw is indented by a distinct shallow bight and the fossa is more narrow than on the right jaw. The posterior and outer margins of the fossa on both jaws are rounded,

whereas the anterior and inner margins are paralleled by a small but conspicous furrow. The upper and lower surfaces of both jaws are generally convex but have many concave areas. The jaws range from 1.1 to 1.9 mm. in length and average 0.6 mm. in width.

Holotype.—Univ. Mo., SCO 10-1.

Occurrence. Snyder Creek fm., Chouteau fm., Auxvasse quarry, Callaway County, Mo.

NEREIDAVUS HARBISONAE Eller
Maxilla I, pl. 6, figs. 21–24

Nereidavus harbisonae ELLER, 1941, p. 325, pl. 37, figs. 1,2,4,5.

Diagnosis.—Medium size, elongate, narrow, asymmetrical pairs of maxilla I with a minutely denticulate inner margin; without a knob or protuberance at the outer-anterior border of the fossa.

Remarks.—*Nereidavus harbisonae* is similar to *N. giganteus* but differs in that the latter is much larger, has a more strongly curved hook and possesses a distinctive fossal knob.

Hypotype.—Univ. Mo., SCO 11–2.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.

Genus PALEOENONITES Eller, 1942

Diagnosis.—Triangular to rectangular shaped jaws of maxilla II with a fang, denticulate inner margin, and an incurved anterior margin ending in a forwardly directed shank.

Type species.—*Paleoenonites accuratus* Eller.

PALEOENONITES DUBIUS, n. sp.
Maxilla II, pl. 6, figs. 35–38

Diagnosis.—Distinctly triangular jaws of maxilla II; a short lateral shank exists on the outer margin of the upper side and extends along the anterior half, nearly perpendicular to the plane of the jaw. The jaws taper towards the posterior end.

Description.—The jaw is triangular in outline with a wide anterior. The anterior margin is slightly convex and somewhat incurved towards the outer side. A shallow bight on the outer-anterior margin extends into a small, poorly developed, forwardly directed shank. Along the inner margin a series of 10 to 12 triangular denticles extends nearly to the posterior end. The first denticle or fang is larger than the others and appears as a continuation of the anterior margin. The fang may be straight or slightly hooked towards the upper side. The remaining denticles decrease uniformly in size to the posterior and may be inclined in that direction. The outer margin of the upper side is extended along the anterior half into a short lateral shank, nearly perpendicular to the plane of the jaw. A narrow fossa extends the full length of the jaw along the outer side. The outer-under margin of the fossa is irregular and broken; the inner-upper margin is thick and rounded and a faint furrow occupies its length. The lateral margins taper to an acute or blunt posterior end. The left and right jaws appear to be symmetrical. The under sides are convex whereas the upper sides are concave—the entire jaw being slightly incurved. The jaws range from 0.4 mm. to 0.9 mm. in length and average about 0.55 mm. in width.

Remarks.—There was some question as to whether or not this species should be referred to the genus *Paleoenonites* or to the genus *Oenonites* Hinde, 1879. The difference lies in the characteristic development of the forwardly directed shank along the anterior of *Paleoenonites.* On many of the collected specimens this shank is apparently not well developed, but since the anterior margins are generally broken, I have placed the jaws in the genus *Paleoenonites* where they most likely belong.

The figured specimens are quite similar to *Paleoenonites angiportus* Eller, 1955, but differ in the nature of the posterior end and the anterior margin. Also, the lateral shank, characteristic of *P. dubius,* is not fully developed in *P. angiportus.*

Holotype.—Univ. Mo., SCO 11-4.

Occurrence.—Chouteau fm., Auxvasse quarry, Callaway County; and near Brown's Station, Boone County, Mo.

Genus STAUROCEPHALITES Hinde, 1879

Diagnosis.—Elongate, compressed, denticulate plates of maxilla II with a relatively large anterior tooth followed by a series of posteriorly directed, diminishing denticles; the fossa occupies the outer margin.

Type species.—*Staurocephalites niagarensis* Hinde.

STAUROCEPHALITES AEQUILATERALIS Eller
Maxilla II, pl. 6, figs. 27–30

Staurocephalites aequilateralis ELLER, 1955, p. 351, pl. 22, figs. 12–29.

Diagnosis.—Medium size, left and right jaws of maxilla II with twelve to fourteen denticles, the first eight of which are large and decrease only slightly in size towards the posterior. The anterior end is truncate whereas the posterior end is rounded.

Hypotype.—Univ. Mo. SCO 12-3.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.; Chouteau fm., near Brown's Station, Boone County, Mo.

STAUROCEPHALITES ALTEROSTRIS Eller
Maxilla II, pl. 6, figs. 31–34

Staurocephalites alterostris ELLER, 1955, p. 353, pl. 23, figs. 8–15.

Diagnosis.—Relatively large, left and right jaws with thirteen to eighteen denticles. The anterior end is extended into an acutely pointed beak whereas the posterior is rounded or irregularly truncate.

Remarks.—Several collected specimens have a distinct ridge on the upper surface near the posterior end, parallel to the denticulation. This is probably not a specific difference however, since many species of the genus *Staurocephalites* show this development.

Hypotype.—Univ. Mo., SCO 13-1.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.

Genus UNGULITES Stauffer, 1933

Diagnosis.—Small, clawlike jaws of maxillae III?, IV, and V with a prominent tooth succeeded on one or both sides by one or more shorter teeth.

Type species.—*Ungulites bicuspidatus* Stauffer.

UNGULITES AGGLOMERATUS Eller
Maxilla III or IV, pl. 6, figs. 13,14

Ungulites agglomeratus ELLER, 1955, p. 364, pl. 25, figs. 7–9.

Diagnosis.—Wide and heavy jaws of maxillae III or IV with one large denticle and a second smaller one. A large rectangular fossa with thickened walls occupies the posterior end.

Hypotype.—Univ. Mo., SCO 13-2.

Occurrence.—Chouteau fm., Auxvasse quarry, Callaway County, Mo.

UNGULITES SPICATUS, n. sp.
Maxilla IV or V, pl. 6, figs. 1–6

Diagnosis.—Small, subquadrate, symmetrical pairs of maxilla IV or V with two or three compressed denticles, the first of which is nearly twice as long as the others. The anterior edge of the fossa is marked by a distinct beak, and the fossa occupies nearly half of the upper surface.

Description.—The jaw is small and all specimens are broken at the posterior end, generally with an irregular margin but sometimes sharply truncate. The entire inner-anterior margin is occupied by two or three triangular-shaped, somewhat compressed, pointed denticles, the two denticle variety being more common. The first denticle is larger than the others and nearly twice as long in comparison. Each of the denticles curves slightly towards the inner side. The inner margin is sharp; the outer margin is rounded or flattened. A faint ridge exists along the outer side of the larger denticle, originating from the base and diminishing near the apex. The median part of the anterior edge of the fossa on the upper surface is marked by a distinct beak which appears as a pinching of the margin. A large fossa occupies nearly half of the upper surface of the jaw. The figured specimens range from 0.34 mm. to 0.48 mm. in length and from 0.1 mm. to 0.2 mm. in width.

Holotype.—Univ. Mo., SCO 13-3.

Paratype.—Univ. Mo., SCO 13-4.

Occurrence.—Snyder Creek fm., Auxvasse quarry, Callaway County, Mo.

BIBLIOGRAPHY

CRONEIS, C. G., 1941, Micropaleontology—past and future: Am. Assoc. Petroleum Geologists, Bull., v. 25, no. 7, p. 1208–1255.

——, & SCOTT, H. D., 1933, Scolecodonts (Abs.): Geol. Soc. America, Bull., v. 44, p. 207.

EHLERS, ERNST, 1864/68, Die Borstenwuermer, nach Systematischen und Anatomischen Unter Suchungen Dargestellt, 2 v., xx+748 p., Leipzig.

——, 1868, Ueber Fossile Wuermer aus dem Lithographischen Schiefer in Bayern: Paleontographica, v. 17, p. 145–175.

ELLER, E. R., 1933, An articulate annelid jaw from the Devonian of New York: Am. Midland Naturalist, v. 14, p. 180.

——, 1934*a*, Annelid jaws from the Upper Devonian of New York: Carnegie Mus. Annals, v. 22, p. 303–316.

——, 1934*b*, Annelid jaws from the Hamilton Group of Ontario County: *Ibid.*, v. 24, p. 51–56.

——, 1936, A new scolecodont genus, *Ildraites* from the Upper Devonian of New York: *Ibid.*, v. 25, p. 73–76.

——, 1938, Scolecodonts from the Potter Farm formation of the Devonian of Michigan: *Ibid.*, v. 27, p. 275–286.

——, 1940, New Silurian scolecodonts from the Albion Beds of the Niagara Gorge, New York: *Ibid.*, v. 28, p. 9–46.

——, 1941*a*, Removal of scolecodonts from the matrix: Pa. Acad. Science Proc., v. 15, p. 119–120.

——, 1941*b*, Scolecodonts from the Windom, Middle Devonian of Western New York: Carnegie Mus. Annals, v. 28, p. 323–340.

——, 1942, Scolecodonts from the Erindale, Upper Ordovician, at Streetsville, Ontario: *Ibid.*, v. 29, p. 241–270.

——, 1944, Scolecodonts of the Silurian Manitoulin dolomite of New York and Ontario: Am. Midland Naturalist, v. 32, p. 732–755.

——, 1945, Scolecodonts from the Trenton series of Ontario, Quebec and New York: Carnegie Mus. Annals, v. 30, p. 119–212.

——, 1946, New scolecodonts from the Kagawong (Ordovician) of Manitoulin Island, Ontario: Pa. Acad. Science Proc., v. 20, p. 71–75.

——, 1955, Additional scolecodonts from the Potter Farm formation of the Devonian of Michigan: Carnegie Mus. Annals, v. 33, p. 347–386.

GRINNELL, G. B., 1877, Notice of a new genus of annelids from the Lower Silurian: Am. Jour. Science, 3d ser., v. 14, p. 229–230.

HARTMAN, OLGA, 1944, Polychaetous annelids. Part V, Eunicea: Allan Hancock Pacific Exped., v. 10, no. 1, p. 1–236, Univ. S. Calif. Press.

HINDE, G. J., 1879, On annelid jaws from the Cambro-Silurian, Silurian, and Devonian Formations in Canada and from the Lower Carboniferous in Scotland: Geol. Soc. London Quart. Jour., v. 35 (139), p. 370–389.

——, 1880, On annelid jaws from the Wenlock and Ludlow Formations of the West of England: *Ibid.*, v. 36 (143), p. 368–378.

——, 1882, On annelid remains from the Silurian strata of the Isle of Gotland: Bihang till kongl. Svenska Akad. Handl., v. 7, "N:05", p. 1–28.

——, 1896, On the jaw apparatus of an annelid from the Lower Carboniferous of Halkin Mountain, Flintshire: Geol. Soc. London Quart. Jour., v. 2 (207), p. 448–450.

KOZLOWSKI, ROMAN, 1956, Sur quelques appareils masticateurs des Annélides Polychètes Ordovicens: Acta Palaeontologica Polonica, v. 1, no. 3, p. 165–210.

LANGE, F. W., 1947, Anelídeos Poliquetas dos Folhelos Devonianos do Paraná: Arquivos do Museu Paranaense, v. 6, art. 5, p. 161–230.

——, 1949, Polychaeta annelids from the Devonian of Parana, Brazil: Am. Paleontology, Bull. 33, no. 134, p. 1–102.

MOORE, R. C., & SYLVESTER-BRADLEY, P. C., 1956, Application for a declaration recognizing parataxa . . . with proposals of procedure for the nomenclature of parataxa: Mimeographed report, Annual Meeting, A.A.P.G. and S.E.P.M.

STAUFFER, C. R., 1933, Middle Ordovician Polychaeta from Minnesota: Geol. Soc. America, Bull., v. 44, p. 1173–1218.

——, 1939, Middle Devonian Polychaeta from the Lake Erie District: Jour. Paleontology, v. 13, no. 5, p. 500–511.

TREADWELL, A. L., 1921, Leodicidae of the West Indian Region: Carnegie Inst. Wash., Pub. 293, v. 15, p. 1–131.

MANUSCRIPT RECEIVED JUNE 24, 1958.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 50–54, PLS. 7,8, 1 TEXT-FIG., JANUARY 1959

THE GASTEROPOD GENERA *LIOMPHALUS* CHAPMAN AND *SCALAETROCHUS* ETHERIDGE[1]

G. M. PHILIP AND J. A. TALENT
Geology Department, University of Melbourne and Geological Survey of Victoria

ABSTRACT—The type species of *Liomphalus* Chapman, 1916, and *Scalaetrochus* Etheridge, 1890, are re-investigated on the basis of topotype material from the Lilydale Limestone (Lower Devonian) of Victoria. *Liomphalus*, generally regarded as a synonym of *Lytospira* Koken, 1896, is shown to be a synonym of *Euomphalus* Sowerby, 1814, as it is based on internal moulds of *Straparolus* (*Euomphalus*) *northi* (Etheridge, 1890). *Trochus* (*Scalaetrochus*) *lindströmi* Etheridge, 1890, the type species of *Scalaetrochus* Etheridge, 1890, is shown to possess a variably callus-filled umbilicus and is not anomphalous as has been presumed. Thus, *Siluriphorus* Cossmann, 1918, should probably be regarded as a junior synonym of *Scalaetrochus*.

INTRODUCTION

IN ORDER to establish a reliable basis for investigation of Middle Palaeozoic gasteropod faunas of Victoria, the genera *Scalaetrochus* Etheridge, 1890 and *Liomphalus* Chapman, 1916 have been re-examined on the basis of material collected over a period of years by Mr. A. A. Baker and the authors, supplemented by material from the collections of the University of Melbourne and Geological Survey of Victoria. All the specimens illustrated or referred to in this paper are stored in the collections of these institutions, with the exception of the types of *Liomphalus australis* Chapman, 1916, which are housed in the National Museum, Melbourne.

The material studied is exclusively from Cave Hill Quarry in the Lilydale Limestone, Lilydale, Victoria, which is the type locality of the type species of the two genera. Of recent years this formation has come to be regarded as Lower Devonian in age (Ripper, 1938; Hill, 1939), but as yet there is no agreement as to precise correlation with the European stages.

Previous work on the gasteropods of the Lilydale Limestone has been by Etheridge (1890, 1891, 1894), Cresswell (1893, 1894), Chapman (1916), and by Knight (1941), who confined his attention to the type species of three nominal genera. The large gasteropod fauna is in need of redescription.

[1] Published by permission of the Department of Mines, Melbourne.

ACKNOWLEDGMENTS

The authors are indebted to the following who have assisted this investigation: to Professor E. S. Hills for the use of the facilities of the Department of Geology, University of Melbourne; to Drs. O. P. Singleton and D. E. Thomas for helpful criticism of the manuscript; to Mr. A. A. Baker for the use of his collection from the Lilydale Limestone, and to Mr. Gill of the National Museum, Melbourne, for the photograph of the holotype of *Liomphalus australis* reproduced in this paper.

LIOMPHALUS

The genus *Liomphalus* was proposed by Chapman (1916) to include smooth, discoidal, loosely coiled gasteropods differing from *Euomphalus* Sowerby in having "smooth, rounded or uniangulate whorls," and from *Straparolus* Montfort in having a "concave spire." Chapman separated his genus from *Lytospira* Koken by the closer coiling and the lack of "scaly ornament." Besides the new species *L. australis*, which was designated type species, Chapman also referred to his genus *Euomphalus disjunctus* Hall, *E. clymeniodes* Hall, *E. triquetris* Lindström, and *E. gotlandicus* Lindström.

In reviewing the genus and relying solely on Chapman's description, Knight (1941, p. 174) stated, "I find it utterly impossible to arrive at any comprehension of the genotype species except by comparison with the adequately described species of other authors referred by Chapman to his

genus. . . ." Later Knight *et al.* (1944, p. 465) placed *Liomphalus* in the synonymy of *Lytospira* Koken.

An examination of the collections available revealed that the genus *Liomphalus* was based on internal moulds of *Straparolus* (*Euomphalus*) *northi* (Etheridge, 1890), one of the most common gasteropods in the Lilydale Limestone. A series of specimens were found in which "*Liomphalus australis*" could be seen emerging from specimens of *Straparolus* (*Euomphalus*) *northi* as more and more shell material had broken away (pl. 7, figs. 1 and 2). We have examined labelled topotypes of "*Liomophalus australis*," including one collected and identified by the late Mr. F. Chapman, in the collections of the Department of Geology, University of Melbourne. These specimens, as well as the holotype and paratype in the collections of the National Museum, Melbourne, clearly show the presence of two bands of shell material between the "whorls" of each "*Liomphalus*" specimen. Indeed this can be seen in Chapman's original figure of the paratype (Chapman, 1916, pl. IV, fig. 30). In most cases it is not difficult to discriminate between matrix and shell material, as the shell material is generally much darker.

This interpretation is in keeping with Chapman's original description. The total absence of surface ornament is consistent with an internal mould and the occasional obscure keeling is an internal reflection of the upper angulation of *S.*(*E.*) *northi.* The apparent separation of the "whorls" is due to the presence of shell between them, so the fact that "*Liomphalus*" appears to be more closely coiled than *Lytospira* naturally follows. The transverse partitions present in the earlier parts of the shell as seen in the paratype of *Liomphalus australis* (Chapman, 1916, pl. IV, fig. 30) are also typical of *S.*(*E.*) northi (pl. 7, fig. 11). This partitioning is in agreement with the various subgenera of *Straparolus.* It therefore follows that *Liomphalus australis* Chapman is a subjective synonym of *Straparolus* (*Euomphalus*) *northi* (Etheridge). The question which now remains is whether *Liomphalus* Chapman, considered in terms of *S.*(*E.*) *northi* rather than "*L. australis*" is significantly different from the subgenera currently embraced by *Straparolus* to justify its retention as another subgenus.

Progressively less conservative views on the subdivision of *Straparolus* have been put forward over recent years. Knight (1934) recognized but two subgenera, *Straparolus S.S.* and *Euomphalus* but subsequently (*Knight et al.* 1944) recognized four valid subgenera and regarded five other nominal genera as synonyms of one or the other. The most recent contribution is by Yochelson (1956), who discriminated five subgenera described as "nodal aggregates along a line of continuous complete intergradation," and regarded one of Knight's subgenera, *Amphiscapha*, as a discrete genus. It is beyond the scope of the paper to consider in detail the usefulness of these "nodal subgenera."

Rather we must endeavour to evaluate the distinguishing features of *Liomphalus* (as based on *S.*(*E.*) *northi*) consistent with this present liberal subdivision of *Straparolus.*

The one striking difference between *S.* (*E.*) *northi* and other angulated nominal genera of this group is the presence of very pronounced transverse ornament on small and medium-sized specimens and on the earlier whorls of large specimens (pl. 7, figs. 1–8). This contrasts with the fine growth lirae described for the type species of *Euomphalus* Sowerby, 1814, *Schizostoma* Bronn, 1834, and *Phymatifer* de Koninck, 1881, all of which in addition have fine revolving lirae along the outer side of the whorl, a feature which has not been observed in *S.* (*E.*) *northi.* Examination of a series of specimens of *S.*(*E.*) *northi* shows that there is such a wide range of variation in the intensity of the transverse ornament that the degree of development of this feature cannot be construed to be of sub-generic significance. This species collected from a small stratigraphic range, shows the variation exhibited in pl. 7. There is a general tendency for the strong transverse costae to be developed at an early stage (pl. 7, figs. 1–5) and these may persist until an individual has reached a diameter of about 7 cm. (pl. 7, figs. 7–9). After this stage the costae become less pronounced and pass gradually into fairly strong growth lirae (pl. 7, fig. 6). As the large specimens which show this change are not particularly common, it is probably a gerontic feature. It

should be pointed out that the transverse ornament is in general less pronounced on the lower side and along the outside of the whorl. The position is somewhat confused by the vagaries of preservation and the fact that most of the specimens appear to have been abraded before burial. Even in the best preserved specimens the strong transverse ornament does not extend across the outer whorl face, which could well explain why no faint revolving ornament has been observed in *S.(E.) northi.*

Some specimens of *S.(E.) northi* have a single well-marked angulation on the upper surface (pl. 7, figs. 1–5) but more generally a weaker angulation is also developed on the lower surface. Occasionally this may be the stronger angulation (pl. 7, figs. 7,8). Specimens may even show a tendency to develop three or four angulations (e.g., pl. 7, figs. 7–9,12). The degree of angulation may even vary within the one specimen. For example, in a sectioned specimen (pl. 7, fig. 12) two angulations can be seen on one side of the specimen while on the other there are three. In general it may be said that the degree of angulation decreases with growth and there is an overall rounding of the whorls. Thus the number of angulations cannot be said to characterize the species, and so certainly cannot be considered as being of subgeneric significance.

Therefore we can find no satisfactory features, considered singly or in combination, to separate *S.(E.) northi* from *Euomphalus* as interpreted by Knight (1944). Indeed, because of the variation in surface ornament and degree of angulation of the whorls in this species, we feel that these characters have not the stability required for them to be regarded as of subgeneric or generic significance within the Euomphalidae. It is concluded then that *Liomphalus* should be regarded as a subjective synonym of *Euomphalus.*

The absence of a calcareous operculum in the Euomphalidae has been considered to be of family importance by some authors (e.g., Knight, 1934, p. 140). It is of some interest then to note that opercula have been observed in a few specimens of *S.(E.) northi,* Isolated specimens of these opercula have been excellently described by Etheridge (1894). When they were originally found in the Lilydale Limestone there was considerable controversy as to whether they were in fact gasteropod opercula, "some taking it for a nummulite, and some for the lid of a coral, others for the vertebra of a fish" (Cresswell, 1894, p. 157). However their true relationship was established by the discovery of specimens of *S.(E.) northi* in which the operculum was *in situ* (Hall, 1893; Cresswell, 1894).

EXPLANATION OF PLATE 7

All figures are unretouched and are natural size unless otherwise stated.

FIGS. *1–5*—*Straparolus* (*Euomphalus*) *northi* (Etheridge). (Melb. Univ. Geol. Dept. 2883.) *1*, oblique apical view. *2*, side view. *3*, basal view. *4*, oblique basal view. *5*, apical view. Specimen possesses one well-defined upper angulation. Note that the transverse ornament is weaker on the lower side and does not extend across the outer side of the whorls.

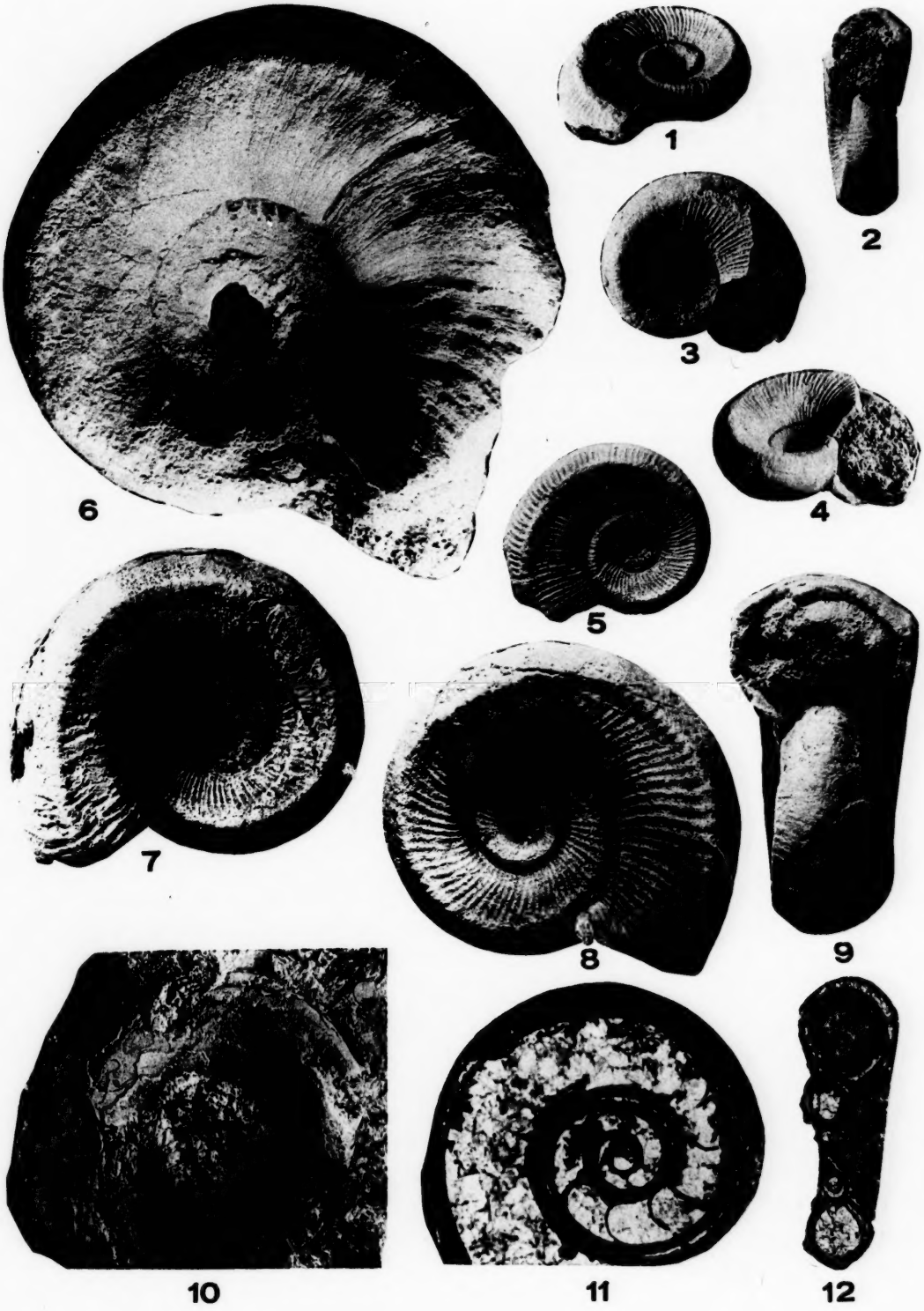
6—*S.(E.) northi* (Etheridge). (Melb. Univ. Geol. Dept. 1041.) Basal view of large specimen showing fairly strong growth lirae. Specimen has no upper angulation. Unconventionally lighted.

7–9—*S.(E.) northi* (Etheridge). (Geol. Survey Vic. 55329.) *7*, apical view. *8*, basal view. *9*, side view. Specimen shows tendency to develop four angulations in the whorl profile. Note also the strong angulation on the lower side of the shell.

10—*Liomphalus australis* Chapman. Holotype (Nat. Mus. Melb. 7609.) National Museum photograph.

11—*S.(E.) northi* (Etheridge). (Geol. Survey Vic. 55332.) Sectioned specimen showing transverse partitions across the earlier parts of the shell. ×2.

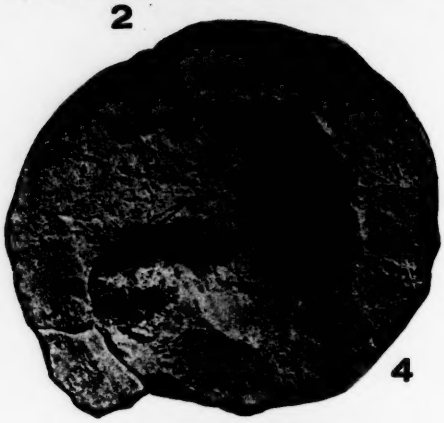
12—*S.(E.) northi* (Etheridge). (Geol. Survey Vic. 55330.) Sectioned specimen showing variation in number of angulations in whorl profile.


1
2
3
4
5
6
7
8
9
10
11
12

1

2

3



4

5

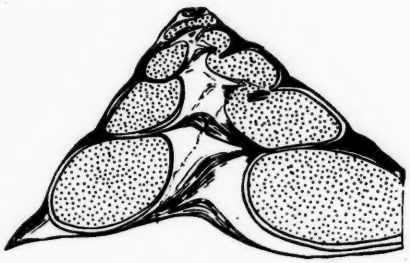
7

8

6

SCALAETROCHUS

Trochus (*Scaleatrochus*) *lindströmi* Etheridge, 1890, the type species of *Scalaetrochus* Etheridge, 1890, has been fully described by Knight (1941, p. 306–7) so no detailed description is necessary. Both Etheridge and Knight described the genus as being anomphalous, although neither author appears to have sectioned a specimen. A typical sectioned specimen (text-fig. 1) shows clearly



TEXT-FIG. *1*—Median section of *Scalaetrochus lindströmi* showing the wide callus-filled umbilicus. ×1¼. (Geol. Survey Vic. 55,331.)

that *Scalaetrochus* is not anomphalous, as has been assumed, but has a moderately wide structural umbilicus, filled with callus. It should be further noted that the callus can be quite variable. Chapman (1916, p. 93) has already observed that some specimens "appear to indicate the presence of a narrow umbilicus."

This changed outlook on the columella structure requires new comparison of *Scalaetrochus* with other Paleozoic trochiform gasteropod genera. The nearest such cryptomphalous genus appears to be *Siluriphorus* Cossmann, 1918, based on *Trochus gotlandicus* Lindström, 1884, a species well described by Lindström (1884) and Knight (1941). In comparison with *Scalaetrochus lindströmi*, it is similar in shape, but is smaller, and has a more strongly deflected outer lip as well as possessing surface ornament which tends to be coarser. In common with *Scalaetrochus*, *Siluriphorus gotlandicus* exhibits extreme varability of callus. "In some specimens it is hardly more than gently concave and without a bordering ridge, in others the concavity as so deep that the specimens appear at first sight to be phaneromphalous" (Knight, 1941, p. 318).

It appears, then, that the differences between *Scalaetrochus lindströmi* and *Siluriphorous gotlandicus* are specific rather than generic, and so *Siluriphorus* Cossmann, 1918 is probably best regarded as a junior subjective synonym of *Scalaetrochus* Etheridge, 1890.

LITERATURE CITED

CHAPMAN, FREDERICK, 1916, New or little-known Victorian fossils in the National Museum, Pt. 19, The Yeringian Gasteropod fauna; Proc. Roy. Soc. Victoria, v. 29, p. 75–103, pls. 1–6.

CRESSWELL, A. W., 1893, Notes on the Lilydale limestone: Proc. Roy. Soc. Victoria, v. 5, p. 38–44, pls. 8–9a.

——, 1894, Additional notes on the Lilydale lime-

EXPLANATION OF PLATE 8

All figures are unretouched and are natural size unless otherwise stated. Figures 3,6,7 are unconventionally lighted to accentuate surface ornament.

FIG. *1*—*Straparolus* (*Euomphalus*) *northi* (Etheridge). (Melb. Univ. Geol. Dept. 2882.) Basal view of naturally broken out specimen showing partial loss of shell material to reveal internal mould; i.e. becoming "*Liomphalus australis*"c.f. Pl. 1, fig. 10.

2—*S.*(*E.*) *northi* (Etheridge). (Melb. Univ. Geol. Dept. 749.) Basal view of naturally broken out specimen in which all shell material has been lost revealing "*Liomphalus australis*."

3—*Scalaetrochus lindströmi* Etheridge. (Melb. Univ. Geol. Dept. 2886.) Enlargement of surface ornament of oblique growth lamellae showing a tendency toward the retention of a flange along an early peripheral angulation. ×4.

4–6—*S. lindströmi* Etheridge. (Melbourne Univ. Geol. Dept. 777.) *4*, basal view showing curved aperture and a line of fracture along the base which coincides with where the shell is thinnest, c.f. Text-fig. 1; unconventionally lighted. *5*, apical view. *6*, side view.

7—*S. lindströmi* Etheridge. (Melb. Univ. Geol. Dept. 2885.) Side view of specimen showing early whorls.

8—*S. lindströmi* Etheridge. (Melb. Univ. Geol. Dept. 2884.) Basal view of a small specimen.

stone: Proc. Roy. Soc. Victoria, v. 6, p. 156–159.

ETHERIDGE, ROBERT, 1890, Descriptions of Upper Silurian fossils from the Lilydale limestone, Upper Yarra District, Victoria: Rec. Australian Museum, v. 1, no. 1, p. 60–67, pls. 8–9.

——, 1891, Further descriptions of Upper Silurian fossils from the Lilydale limestone, Upper Yarra district, Victoria: Rec. Australian Mus., v. 1, no. 7 p. 125–130, pls. 18–19.

——, 1894, An operculum from the Lilydale limestone: Proc. Roy. Soc. Victoria, v. 6, p. 150–155, pl. 9.

HALL, T. S., 1893, *Discussion of July 14th, 1892:* Proc. Roy. Soc. Victoria, v. 5, p. 260.

HILL, DOROTHY, 1939, The Devonian rugose corals of Lilydale and Loyola, Victoria: Proc. Roy. Soc. Victoria, v. 51. p. 219–256, pls. 13–16.

KNIGHT, J. B., 1934, The gastropods of the St. Louis, Missouri, Pennsylvanian outlier: VII-the Euomphalidae and Platyceratidae: Jour. Paleontology, v. 8, p. 139–166, pls. 20–26.

——, 1941, Paleozoic gastropod genotypes, Geol. Soc. America, Spec. Paper 32, p. 1–510, pls. 1–96.

——, et al., 1944, *in* SHIMER, H. W., & SHROCK, R. R., Index fossils of North America, Chapter X, p. 433–479, New York, John Wiley & Sons.

LINDSTRÖM, G., 1884, On the Silurian Gastropoda and Pteropoda of Gotland: K. Svensk, Vet.-Akad. Handl., Bd. 19, no. 6, p. 1–250, pls. 1–21.

RIPPER, ELIZABETH, 1938, Notes on the middle Palaeozoic stromatoporoid faunas of Victoria: Proc. Roy. Soc. Victoria, v. 50, p. 221–243.

YOCHELSON, E. L., 1956, Permian Gastropoda of southwestern United States, I Euomphalacea Trochonematacea, etc.; Bull. Am. Mus. Nat. History, v. 110, art. 3, p. 177–275, pls. 9–24.

MANUSCRIPT RECEIVED JULY 30, 1958.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 55–62, PLS. 9, 10, 1 TEXT-FIG., JANUARY 1959

ORDOVICIAN AND SILURIAN CYRTOGOMPHOCERATIDAE (NAUTILOIDEA) FROM THE OSLO REGION, NORWAY

WALTER C. SWEET
The Ohio State University, Columbus

ABSTRACT—Two species of discosorinid nautiloids, *Cyrtogomphoceras* sp. cf. *C. thompsoni* Miller & Furnish, and *Parryoceras strandi*, n. sp., are illustrated and described from the Upper Ordovician of the Oslo region, Norway. Two additional nautiloids from the Norwegian Lower Silurian represent a new genus and species of Cyrtogomphoceratidae, for which the name *Konglungenoceras norvegicum* is proposed. Neither *Cyrtogomphoceras* nor *Parryoceras* has previously been reported with certainty from Europe; in addition, the *Cyrtogomphoceras* exhibits endocones in the siphuncle, structures not heretofore known to occur in the Cyrtogomphoceratidae. *Konglungenoceras* is like the phragmoceratid *Protophragmoceras* externally, but similar to advanced Cyrtogomphoceratidae internally. It may represent an unrecognized discosorinid family, perhaps including the Devonian genus, *Alpenoceras*.

INTRODUCTION

REPRESENTATIVES of the nautiloid suborder Discosorina are abundant at many horizons in the Lower Paleozoic of North America and closely similar species are well represented in strata of similar age at localities in Norway, Sweden, Estonia, and Czechoslovakia. All of these cephalopods are part of a widespread boreal, or "arctic" fauna that spread southward into both North America and Europe several times during the Ordovician and Silurian. Representatives of this boreal fauna are, therefore, of considerable value in intercontinental correlations and undescribed forms merit more than ordinary attention. Several such specimens occur in collections at the Paleontological Museum in Oslo, Norway, and they form the basis for this report.

One of these specimens, a *Cyrtogomphoceras* similar to *C. thompsoni* Miller & Furnish, came from the Upper Ordovician Gastropod limestone (substage 5a) of the Ringerike district, near Oslo. This specimen is unique, insofar as the writer is aware, in that the parietal deposits lining its siphuncle are produced adapically into well defined endocones, structures not heretofore known to occur in either *Cyrtogomphoceras* or the Cyrtogomphoceratidae. Furthermore, this specimen is the first undoubted representative of *Cyrtogomphoceras* to be collected from strata other than those of the North American Upper Ordovician.

One of the several paratypes of *Beloitoceras heterocurvatum* Strand, also from the Gastropod limestone of the Ringerike district (northwest of Oslo) is clearly an endogastric discosorinid (rather than a *Beloitoceras*) and is strikingly similar in many repects to the types of *Parryoceras euchari* Sweet & Miller, a species known only from Upper Ordovician strata on Cornwallis Island in the Canadian Arctic Archipelago. The Norwegian specimen differs in certain features from the Canadian specimens, however, and for that reason is herein referred to a new species, *Parryoceras strandi*.

Two additional specimens, representing an undescribed genus and species of Cyrtogomphoceratidae, were collected many years ago from Lower Silurian (lower Llandoverian) rocks in the Oslo region. These specimens, for which the name *Konglungenoceras norvegicum* is proposed, belong to an endogastric species of nautiloids with a siphuncular structure similar both to that of *Cyrtogomphoceras* sp. cf. *C. thompsoni*, described below, and *Tuyloceras percurvatum*, an exogastric lowoceratid. The gross conch shape of this new species suggests *Protophragmoceras*, but species of that genus are not known definitely to have either endosiphuncular deposits or aperturally contracted body chambers. *Konglungenoceras* seems significant, then, for it suggests that species of *Cyrtogomphoceras* with endocones may have given rise in the Upper Orodovician or early Silurian to a stock of endogastric cyrtoceracones, distinguishable from

the Phragmoceratidae by the contracted body chamber (but unvisored aperture) and the presence of parietal deposits and endocones in the siphuncle, and from the Lowoceratidae and Discosoridae by their endogastric conchs. This stock may well include the Devonian *Alpenoceras* and should probably be recognized by a new familial name.

The writer is indebted to Dr. Gunnar Henningsmoen, Curator of fossil invertebrates at the Paleontological Museum, Oslo, Norway, for arranging to loan him the material upon which this report is based and for his many courtesies during the writer's stay in Oslo. Several of the illustrations were prepared by Miss Bergljot Mauritz, faculty photographer of the University of Oslo, to whom the writer expresses his gratitude. Other photographs and drawings were prepared by the writer and were financed by a liberal grant from the Graduate School of The Ohio State University.

SYSTEMATIC DESCRIPTIONS

Family CYRTOGOMPHOCERATIDAE Flower, 1940

Genus CYRTOGOMPHOCERAS Foerste, 1924

CYRTOGOMPHOCERAS sp. cf. C. THOMPSONI Miller & Furnish

Pl. 9, figs. 1–4

Cf. *Cyrtogomphoceras thompsoni* MILLER & FURNISH, 1937, p. 549–550, pl. 68, fig. 3.

The collections of the Paleontological Museum in Oslo contain a single, well preserved, but incomplete representative of *Cyrtogomphoceras* that is closely similar in overall proportions to the figured type of *C. thompsoni* Miller & Furnish, and may well be conspecific with it. However, the writer cannot refer the specimen at hand to Miller & Furnish's species with certainty, for nothing is known of the internal structures of its type and the Norwegian specimen exhibits endosiphuncular features not previously known in any species of *Cyrtogomphoceras*.

The Norwegian specimen is an internal mold, 155 mm. long, which represents the adapical part of the body chamber and 17 camerae of the phragmocone. The conch is breviconic, slightly compressed laterally, and curved endogastrically. At the adapical end of the specimen, the height of the conch is about 49 mm.; the width at the same place is estimated to have been about 46 mm. The conch reaches its maximum gibbosity at a point about 73 mm. orád of its adapical end, and, at this place, has a height and width of 62 and 53 mm., respectively. The dorsum is prominently and rather uniformly convex, having a radius of curvature of about 86 mm. The ventral margin of the conch is incomplete due to weathering, but it appears to have been virtually straight, or perhaps to have been somewhat convex over the adapical portion of the body chamber and the adoral part of the phragmocone. The apertural margin of the conch is not preserved, but it is clear that the conch contracted from all sides toward the aperture.

Camerae are short, some 14 occurring laterally in a distance equivalent to the maximum dorsoventral diameter of the conch. Adapically, the sutures are simple and directly transverse to the long axis of the conch; adorally, they tend to swing rather prominently dorsad from the venter and to develop broad, shallow lateral lobes. The youngest septum is incomplete; that is, when traced dorsad from the siphuncle, this septum intersects and apparently becomes continuous with the septum immediately apicad of it.

The siphuncle is well preserved and its configuration is portrayed in figures 2 and 4 on Plate 9. As can be seen in these figures,

---

EXPLANATION OF PLATE 9

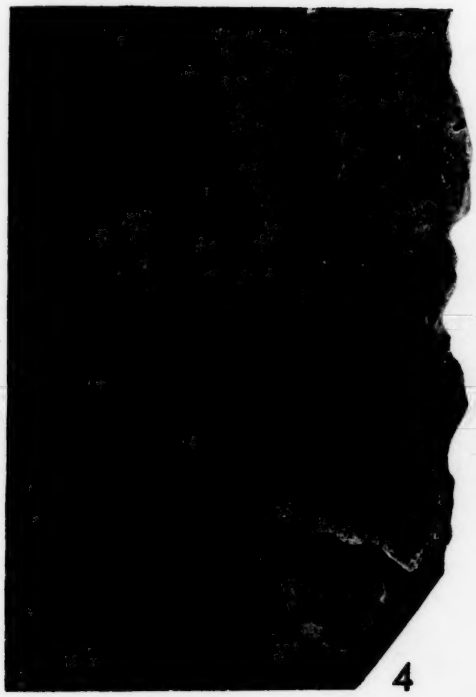
FIGS. *1–4*—*Cyrtogomphoceras* sp. cf. *C. thompsoni* Miller & Furnish. Fig. 1 and 3 are ventral and lateral views, ×0.75; fig. 2 is a view of a dorsoventral section through the same specimen, ×0.75; fig. 4 is an enlarged view of the adapical portion of the section shown in fig. 2. Note heavy parietal deposits and well developed endocones. P.M.O. 69311, probably from substage 5a (Gastropod limestone), Ringerike district, Oslo region, Norway.

5–6—*Parryoceras strandi*, n. sp. Lateral and dorsal views of the holotype, ×1. P.M.O. I 1195, substage 5a (Gastropod limestone), Stavnestangen, Ringerike district, Oslo region, Norway.

1

2

3



4

5

6

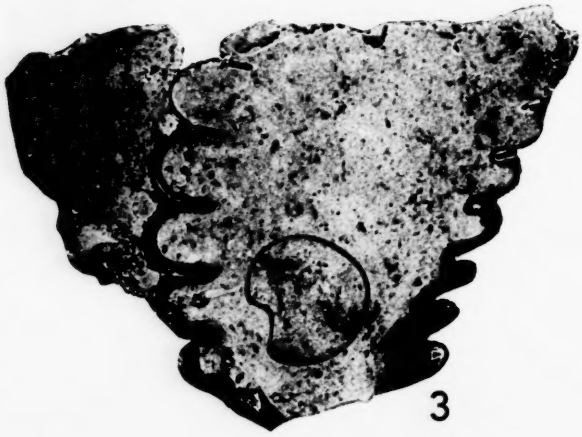
1

2

6

4

5



3

the siphuncle is ventral and submarginal in position, somewhat more than a third the width of the conch in diameter, and composed of short, nummuloidal segments. Septal necks are cyrtochoanitic, relatively long, and abruptly recurved (but not recumbent). Adorally, the connecting rings appear to be of approximately the same thickness and composition as the septa, but their relationships are obscured by pyritization. Adapically, however, the connecting rings are somewhat thicker than adorally; near the septal foramen, they are differentiated into two indistinct layers and are somewhat thicker there than within the camerae. Presumably, the thickened and longitudinally differentiated adapical ends of these rings represent bullettes; they are not, however, particularly prominent. Endosiphuncular deposits, consisting of dark, laminated parietal deposists, occupy the adapical 5 camerae of the specimen. These deposits are produced adapically into distinct endocones, built up of broad, short cones, the inner surfaces of which appear to be annulated. In addition to these endosiphuncular annuli, there is a suggestion (at two points opposite the third septal foramen orad of the specimen's adapical end) of adorally curved diaphragms, produced into, or perhaps across the central conical concavity ("endosiphotube") of the siphuncle.

Remarks.—The specimen just described has a slightly greater dorsal convexity and somewhat shorter camerae than the type of *Cyrtogomphoceras thompsoni* Miller & Furnish, but in other comparable proportions the two are virtually identical. Endosiphuncular deposits such as those found in the Norwegian specimen have not been reported in other described representatives of *Cyrtogomphoceras* and they do not appear to have been noted in other closely allied nautiloid genera of the Cyrtogomphoceratidae (Flower & Teichert, 1957). However, this may be due in large part to the fact that the siphuncular structure is known in only a few representatives of the Cyrtogomphoceratidae, and, in the specimens for which the internal structures are known, it is possible that no endosiphuncular deposits were ever present in the portion of the siphuncle sectioned. By and large, then, although the lack of secondary organic deposits may be a reasonably good criterion by which the siphuncle can be distinguished from other Discosorina, for example, the Westonoceratidae, it does not appear to be an infallible familial characteristic. The presence of endocones and parietal laminae in the siphuncle of at least this one cyrtogomphoceratid tends to heighten the similarity between forms like this and other discosorinids; that is, it suggests that a similar pattern of tissues, capable of similar functions, existed within the siphuncle of all members of the suborder.

Occurrence.—No label accompanies the specimen just described, but it is known to have been collected in the Ringerike district of the Oslo region. It is lithologically similar to other specimens in the writer's collections from the Gastropod limestone (substage 5a), the penultimate division of the Norwegian Upper Ordovician, and it almost certainly came from one of the several richly fossiliferous exposures of that unit in the Ringerike district.

Repository.—Paleontological Museum, Oslo, 69311. The specimen has been sectioned, hence consists of several pieces, all of which bear the same catalogue number.

EXPLANATION OF PLATE 10

FIGS. *1–5*—*Konglungenoceras norvegicum*, n. gen. & sp. Fig. 1 and 2 are ventral and lateral views of an isolated siphuncle, ×1.5; fig. 3 is a view of the same specimen sectioned in a dorsoventral plane, ×1.7. Fig. 4 and 5 are ventral and lateral views of the holotype, ×0.5. Both specimens are from Lower Silurian Stricklandia series (substage 6b), Konglungen, Asker, Oslo region, Norway. P.M.O. I 1064 and I 1065, respectively.

6—*Parryoceras strandi*, n. sp. View of a somewhat oblique lateral polished section through the adoral five siphuncular segments of the holotype, ×1.7. P.M.O. I 1195, substage 5a (Gastropod limestone), Stavnestangen, Ringerike, Oslo region, Norway.

Genus PARRYOCERAS Sweet & Miller, 1957

Type species: *Parryoceras euchari* Sweet & Miller, 1957.

The genus *Parryoceras* was erected (Sweet & Miller, 1957, p. 53) for the reception of two specimens from the Upper Ordovician Cape Phillips formation on Cornwallis Island, in the Canadian Arctic Archipelago. These specimens represent a species of nautiloid cephalopods distinguished from other species in the possession of a compressed, faintly cyrtoceraconic, endogastric conch and an exosiphuncle composed of recumbent septal necks and thickened connecting rings that are somewhat expanded in the septal foramen to form small, but distinct bullettes. No parietal or other endosiphuncular deposits are known to occur in the types of *Parryoceras euchari*, hence the genus is believed to be closely related to described representatives of the Cyrtogomphoceratidae, particularly to *Strandoceras* Flower. *Parryoceras* differs from *Strandoceras*, however, in that the conch is not strongly curved and somewhat more compressed. Furthermore, the bullettes of *Parryoceras* are not as well defined as are those in known representatives of *Strandoceras*.

To this discussion, it should also be added that the types of *Parryoceras euchari* exhibit, at the adapical end of the internal mold of the body chamber, a narrow, transverse zone of subquadrangular loculi, indicating the presence on the shell interior of a similarly located transverse band of nodes or tubercles. The adoral edge of this "basal zone" is marked by a fine, raised line (an incised groove on the original shell) that presumably represents the adoral edge of the annular elevation—the shell zone to which the retractor, mantle, and subepithelial muscles of the animal were attached. Furthermore, the ventral portion of the tuberculate "basal zone" is marked by well defined, subovate pits that are considerably larger than the other circumferential loculi and are now thought to represent the loci of attachment of the "shell-", or retractor muscles (Sweet, 1959).

In 1933, Strand proposed the specific name, *Beloitoceras heterocurvatum*, for six Upper Ordovician cyrtoceracones from the Isotelus and Gastropod limestones (substages 4d and 5a, respectively) of the Oslo region and the Lyckholm formation of Estonia. As the specific name suggests, Strand included in *B. heterocurvatum* both endogastric and exogastric forms that appeared similar to him in other characteristics. The holotype of the species, two other Norwegian representatives, and one of the two specimens from Estonia included by Strand in *B. heterocurvatum*, are exogastric forms that almost certainly belong in *Beloitoceras* as that genus is currently interpreted. However, the two endogastric forms included by Strand in this species (one from the Oslo region; one from Estonia) are clearly discosorinids and must be removed from *Beloitoceras heterocurvatum*. Only one one of these specimens, the one from the Oslo region, is available to the writer, and it undoubtedly belongs in an undescribed species of *Parryoceras*. Strand (1933, pl. X, fig. 10) figures only a longitudinal section of the siphuncle of the endogastric Estonian form. This illustration indicates that it is somewhat different internally than the specimen at hand, although it is probably also referable to *Parryoceras*.

PARRYOCERAS STRANDI Sweet, n. sp.
Pl. 9, figs. 5,6; Pl. 10 fig. 6

Beloitoceras heterocurvatum STRAND (part), 1933, Norsk Geol. Tidsskr., bd. 14, p. 77, pl. 10, fig. 11 (not pl. 10, figs. 8,9,10).

The holotype and only known representative of this new species is an internal mold of the body chamber and 13 adoral camerae of a compressed, endogastric cyrtoceracone, the overall length of which is about 70 mm. The conch cross section is lachrymiform, the venter being more acutely rounded than the dorsum. At the adapical end of the body chamber, dorsoventral and lateral diameters are 38 and 33 mm., respectively; at the adapical end of the specimen, comparable diameters are 25 and 21 mm., respectively. The dorsal margin of the conch is broadly convex throughout its entire preserved length; the venter is slightly concave adapically, but essentially straight or even faintly convex in its adoral third.

The camerae are rather closely spaced, about 6 occurring in a dorsal length equivalent to the maximum dorsoventral diameter of the conch. The septa are smooth,

shallow, and extend adapically for a distance equivalent to the length of half a camera. The sutures are slightly sinuous as a result of conch compression, forming broad lateral lobes and dorsal and ventral saddles, the latter having sharp, angular crests in the ventral mid-line.

The surface of the internal mold displays a series of rather prominent ribs or ridges that have rounded crests and are rather uniformly spaced about the circumference of the conch. In the dorsal and dorsolateral zones, these ribs or ridges exhibit a curvature like that of the dorsal margin of the conch, but ventrally and ventrolaterally, they show a configuration like that of the venter.

The siphuncle is relatively large, compressed, and located at the ventral (or concave) margin of the conch. It is composed of short, recumbent septal necks and thick, only slightly expanded connecting rings that outline subquadrate siphuncular segments. At the septal foramen, the adapical ends of the connecting rings are clearly divided into two longitudinal laminae. The outermost of these two ring layers is dark in color and considerably thicker than the innermost one. The inner layer is clear and relatively thin; at, and immediately apicad of the septal foramen, both layers increase in width to form a slightly pendant bullette. No endosiphuncular parietal deposits can be distinguished.

Remarks.—The specimen just described has been carefully compared with the two known representatives of *Parryoceras euchari* Sweet & Miller, the type species of *Parryoceras*. *P. strandi* is somewhat more curved dorsally than *P. euchari;* the latter is more strongly compressed and its sutures are, for that reason, more sinuous than those of *P. strandi*. With the exception of these slight differences, however, the two species are very similar morphologically, and there can be but little doubt that they are closely related genetically. The types of *P. euchari*, the only other species of *Parryoceras* heretofore described, came from an Upper Ordovician horizon in the Cape Phillips formation on the Marshall peninsula of Cornwallis Island, in the Canadian Arctic Archipelago. The Gastropod limestone (substage 5a) of Norway, which yielded the type of *P. strandi*, is likewise Upper Ordovician in age.

Occurrence.—Gastropod limestone (substage 5a), Stavnestangen, Ringerike (Oslo region), Norway. The single known specimen was collected in 1914 by the late Professor Johan Kiaer.

Repository.—Holotype, Paleontological Museum, Oslo, I 1195 and I 1198 (two portions of the same specimen, numbered separately).

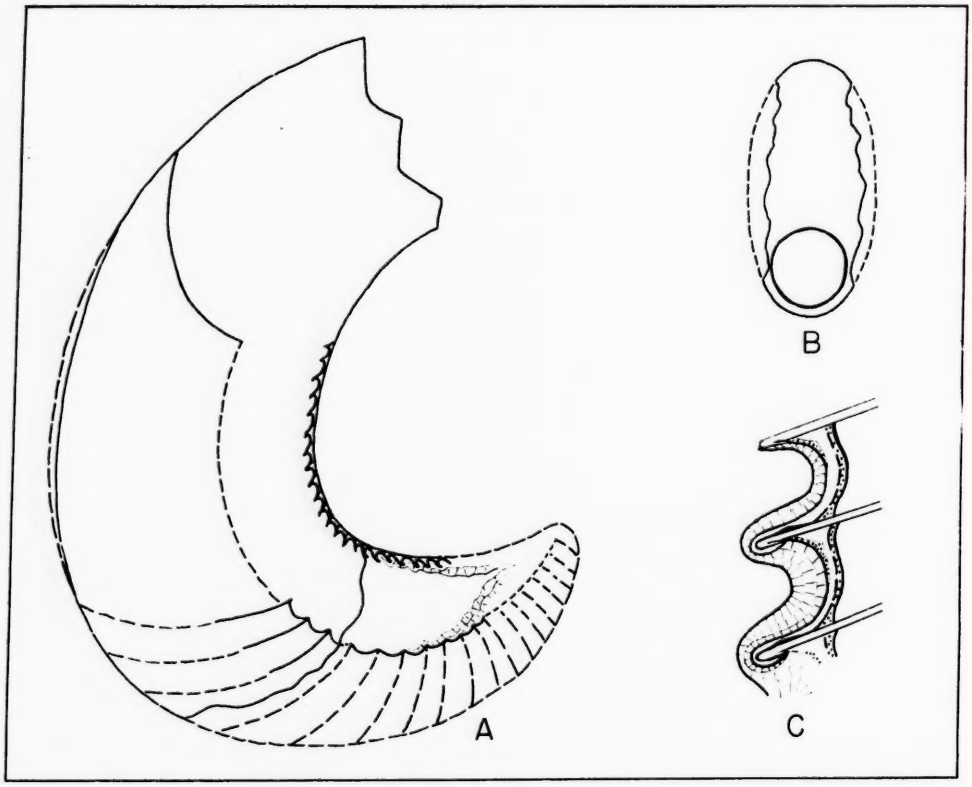
Genus KONGLUNGENOCERAS Sweet, n. gen.

Type species: Konglungenoceras norvegicum Sweet, n. sp.

Name.—The type species of this new genus is known from two specimens, both collected on Konglungen, Asker, an island in the Oslofjord, near Oslo, Norway. The generic name, therefore, refers to the type locality.

Diagnosis.—Laterally compressed, endogastric cyrtoceracones with contracted apertures and large, nummuloidal siphuncles composed of recumbent septal necks and thick, laminated connecting rings that may be somewhat thinner adorally than adapically, but are not produced into pendant bullettes in the septal foramina. Endosiphuncular deposits restricted to adapical portion of siphuncle where they consist of heavy parietal laminae extended adapically to form endocones.

Remarks.—*Konglungenoceras* is clearly distinct from previously described Discosorina, but its relationships to known genera are problematical. Available information indicates rather convincingly that the large, nummuloidal siphuncle is ventral in position and the conch endogastric, for the few growth lines preserved on the holotype appear to form a shallow sinus on the concave, siphuncular side, but to be straight and directly transverse on the convex, antisiphuncular side. This fact alone suggests reference to either the Cyrtogomphoceratidae or the Phragmoceratidae, for a majority of the endogastric Discosorina belong in one or the other of these two families. Furthermore, the aperture of *Konglungenoceras* is contracted in a fashion like *Cyrtogomphoceras* and the siphuncle is comparable in size and proportions to that of the latter genus. On the other hand, endosiphuncular deposits are known to occur in only one



TEXT-FIG. *1*—*Konglungenoceras norvegicum*, n sp. A, reconstruction of a complete conch, in longitudinal section. Based on presumed association of the holotype and paratype. Ca. ×½. B, outline of conch at adapical end of holotype. Dashed lines indicate probable position of sides prior to weathering. ×½. C, schematic view of the ventral parts of two segments of the siphuncle, based on the specimen shown in fig. 1–3, Plate 10. Septa and connecting rings white; vinculum and external lamina derived from vinculum stippled; parietal deposits cross-lined.

representative of the Cyrtogomphoceratidae, the *Cyrtogomphoceras* described in an earlier part of the present contribution, and there is a suggestion that the rings of *Konglungenoceras norvegicum* are somewhat thinner in adoral camerae of the phragmocone than in adapical camerae. This general sequence of siphuncular structures is reminiscent of *Tuyloceras percurvatum*, the only adequately known representative of the Lowoceratidae (Flower, *in* Flower & Teichert, 1957, p. 97). In *Tuyloceras*, however, the adapical portions of the connecting rings form inflated bullettes, and the conch is exogastric, or, at least, the siphuncle is adjacent to the convex (rather than the concave) margin of the conch. Ignoring the slight growth line sinus on its siphuncular side, *Konglungenoceras* might, then, be interpreted as an exogastric lowoceratid with a dorsal siphuncle, or, perhaps, even as an endogastric member of the Lowoceratidae.

The gross morphology of the conch in *Konglungenoceras norvegicum* is more like that of strongly curved representatives of *Protophragmoceras*, with the exception that species of that genus are not known to have adorally contracted body chambers. Furthermore, endosiphuncular deposits are not known with certainty to occur in either *Protophragmoceras* or the Phragmoceratidae, and the adapical ends of the connecting rings are produced into pendant bullettes in a majority of the known species of this family. It should also be pointed out that the siphuncle of the Phragmoceratidae is typically

rather small in diameter; in no described phragmoceratid species does the siphuncular diameter approach that of *Konglungenoceras norvegicum.*

It seems to the writer that fewer problems are encountered in assigning *Konglungenoceras* to the Cyrtogomphoceratidae rather than to either the Lowoceratidae or Phragmoceratidae, although, as the above remarks indicate, a reasonable case could be made for either of the two latter families as a proper receptacle. It may well be that *Konglungenoceras* is a provincial, Scando-Baltic derivative of *Cyrtogomphoceras* (or *Strandoceras*), in which bullettes are suppressed and siphuncular structure modified in a fashion similar to that known to have occurred in the Lowoceratidae and Discosoridae, but independently of the stock represented by those families. The interesting possibility is also suggested that the anomalously endogastric, Devonian genus *Alpenoceras*, assigned by Flower (*in* Flower & Teichert, 1957) to the otherwise exogastric Discosoridae, might well be a cyrtogomphoceratid, or related, at least, to a stock originating in the Cyrtogomphoceratidae, but characterized by a thick-ringed siphuncle, small or vestigial bullettes, and bearing heavy, relatively simple endosiphuncular deposits adapically. There is, then, the possibility of homeomorphy between the later derivatives of the two principal evolutionary stocks of the Discosorina; that is, between the Westonocertidae-Lowoceratidae-Discosoridae on the one hand, and the Cyrtogomphoceratidae-Phragmoceratidae on the other. If such is eventually found to be the case, *Konglungenoceras*, *Alpenoceras*, and related forms should probably be referred to a new family, related ancestrally to species of *Cyrtogomphoceras* with endosiphuncular deposits and mimicking the Lowoceratidae and Discosoridae in siphuncular structure, but not in siphuncular position.

KONGLUNGENOCERAS NORVEGICUM Sweet, n. sp.

Pl. 10, figs. 1–5; text-fig. 1A-C

This new species is based on two fragmentary specimens, probably originally parts of the same conch, found in strata of the Stricklandia series, on Konglungen, Asker, in the Oslo region. Both of these specimens have been sectioned longitudinally through the siphuncle; the larger of the two (represented by figures 4 and 5 on Plate 10) is herein designated the holotype.

The holotype of *Konglungenoceras norvegicum*, n. sp., is an internal mold, some 178 mm. in overall length, which represents 15 camerae of the phragmocone and the adapical portion of the body chamber. The specimen is complete neither adapically nor adorally, and portions of the sides have been removed by erosion. Nevertheless, it is clear that the conch was laterally compressed and that dorsoventral and lateral diameters at the specimen's adapical end were approximately 68 and 36 mm., respectively. At the adoral end of the phragmocone, comparable measurements are 65 and 48 mm. The apertural margin is not preserved, but at the adoral end of the specimen, dorsoventral and lateral diameters are 54 and 36 mm., indicating that the shell contracted somewhat adaperturally.

Camerae are closely spaced, about 9 occurring ventrally in a distance equivalent to the adapical lateral diameter (36 mm.) of the specimen. None of the septa are complete for the full height of the conch, hence no accurate information concerning their configuration or that of the sutures is available. Presumably, the sutures form dorsal and ventral saddles and broad, relatively shallow (but probably asymmetrical) lateral lobes. Remnants of the inner part of the test are preserved ventrally and dorsally near the adoral end of the phragmocone. These suggest that the shell surface was very faintly cancellated; growth lines appear to form a slight sinus on the venter, but to be straight and directly transverse to the axis of the conch on the dorsum.

The siphuncle is ventral and marginal in position. At the septal foramen, it has a diameter slightly less than a third the height of the conch; within the camerae, however, its segments expand so that the diameter is slightly greater than a third the conch height. In the holotype, only the two and a half adapical segments are complete, the septa and siphuncular walls having been destroyed dorsally in the balance of the phragmocone. These segments indicate, however, that the septal necks are cyrtochoanitic and recumbent, with rather long

brims. The connecting rings are thick and longitudinally laminated, but their proximal ends do not appear to be inflated into pendant bullettes. The ventral portions of the siphuncular segments in the adoral 5 camerae are not well preserved, but they indicate that the rings are thick, and traces of laminae can be detected. However, there is a suggestion that the rings were not as thick adorally as are those in adapical camerae, and the outer layer, developed from the vinculum and noted in earlier segments, does not appear to be present. No indication of endosiphuncular or cameral deposits is evident.

The structure of the adapical portion of the siphuncle of *Konglungenoceras norvegicum* is well displayed by a small specimen (Plate 10, figs. 1–3) from the same horizon and locality as the holotype and probably once a part of the same conch. This specimen has an overall length of 38 mm. and represents seven segments of the siphuncle. This siphuncular fragment is circular in cross section, had adapical and adoral diameters of 19 and 28 mm., and was probably related to the holotype in the fashion suggested by text-figure 1A. A longitudinal dorsoventral section of this specimen indicates that the septal necks are long and recumbent, and that the connecting rings are thick and clearly differentiated into several longitudinal laminae. However, these laminae do not expand within the septal foramina to form bullettes. Recrystallization has obscured the fine structure of the connecting rings, but it appears that the vinculum is subdivided adorally within each segment, the outer portion being produced adapically as a rather thick, granular "coating" about the siphuncular segment. Other structures visible are shown schematically in text-figure 1C.

Endosiphuncular deposits, in the form of thick parietal laminae, line the adapical 5 segments of the siphuncle, and are extended adapically to form endocones. Only the adoral portions of these endocones are retained in the specimen at hand, but it should perhaps be noted that the inner surfaces of these structures are marked by rather prominent annuli within the septal foramina. The relationship of the parietal laminae and endocones to the ectosiphuncle is shown in text-figure 1C.

Occurrence.—Both of the two known representatives of *Konglungenoceras norvegicum* were collected from strata in the middle portion (substage 6b) of the Stricklandia series, on the southeast side of Konglungen, an island in the Oslofjord some 14.5 km. southwest of the City Hall in Oslo. The Stricklandia series, as a whole, is about 170 meters thick in the Oslo region, and is equated in its entirety to part of the lower Llandoverian of Great Britain.

Repository.—Paleontological Museum, Oslo, I 1065 (holotype), I 1064 (paratype).

REFERENCES

FLOWER, R. H., & TEICHERT, CURT, 1957, The cephalopod order Discosorida: Univ. Kansas Paleont. Contrib., Mollusca, art. 6, 144 p., 43 pls., 34 figs.

MILLER, A. K., & FURNISH, W. M., 1937, Ordovician cephalopods from the Black Hills, South Dakota: Jour. Paleontology, v. 11, p. 535–551, pls. 66–69.

STRAND, TRYGVE, 1933, The Upper Ordovician cephalopods of the Oslo area: Norsk Geologisk Tidsskr., bd. 14, hft. 1, p. 1–117, pl. I–XIII.

SWEET, W. C., 1959, Muscle-attachment impressions in some Paleozoic nautiloid cephalopods: Jour. Paleontology, v. 33 (in press).

——, & MILLER, A. K., 1957, Ordovician cephalopods from Cornwallis and Little Cornwallis Islands, District of Franklin, Northwest Territories: Geol. Survey Canada, Bull. 38, 86 p., 8 pls., 12 figs.

MANUSCRIPT RECEIVED JULY 9, 1958.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 63–75, PLS. 11–14, JANUARY 1959

ARCHAEOCYATHA FROM THE COLVILLE AND SALMO AREAS OF WASHINGTON AND BRITISH COLUMBIA

ROBERT G. GREGGS
University of British Columbia, Vancouver, B.C.

ABSTRACT—In 1948 and 1950 Dr. H. Little of the Geological Survey of Canada collected Archaeocyatha from the Lower Cambrian outcrops of Colville, Washington, and Salmo, British Columbia. These collections were later supplemented by Dr. V. J. Okulitch with fossils from the same localities.

The Archaeocyatha of the Salmo area occur in a narrow band of limestone in the basal Laib formation. Those of the Colville area, Washington, were found in an outcrop of Old Dominion limestone. Numerous species are present in both localities, and two new species are described: *Ethmophyllum lineatus* from the Laib formation and *Syringocnema colvillensis* from the Old Dominion limestone.

The species *Archaeopharetra typica*, *Monocyathus* sp., and *Claruscyathus solidus* are reported for the first time from North America. *Claruscyathus solidus* is particularly abundant at the Colville locality.

INTRODUCTION

IN 1948, Dr. H. Little of the Geological Survey of Canada, made a fine collection of Archaeocyathids from the Lower Cambrian of the Salmo area. The fossils were collected "in the eastern part of the map area, from the 200-foot band of limestone at the base of the Laib group, from a point nearly 5 miles to the north" (Little, 1950). This material was sent to the University of British Columbia for study by Dr. V. J. Okulitch. The faunal list of Archaeocyathids from this area was published in Dr. Little's report (Little, 1950), but no detailed descriptions of these Archaeocyathids were made.

In the following year, 1949, Dr. Little made another extensive collection of Archaeocyathids from the Colville area, from a west-facing bluff of Old Dominion limestone about 1 mile north of Colville, Washington. This material has not previously been examined in any detail.

Both of the above collections were later supplemented with material collected by Dr Okulitch from the same localities.

The Archaeocyathids were preserved in limestones of three main types. The limestone containing the best preserved fossils was medium grey, fine-grained, and contained little argillaceous material. A second limestone contained such quantities of brown argillaceous material that the latter replaced outer portions of the Archaeocyathids. Consequently, the preservation of fossils in this matrix was poor. The third limestone was a creamy white, slightly metamorphosed rock in which the Archaeocyathids appeared as mere shadowy outlines. The specific determination of fossils in this last rock type was very difficult.

Sixty thin-sections containing 275 specimens were made from the Colville material, and eleven polished rock samples incorporating some fifty specimens from the Salmo area were studied.

SYSTEMATIC DESCRIPTIONS

Class ARCHAEOCYATHEA Okulitch, 1943

Order AJACICYATHIDA Bedford & Bedford, 1939

Family AJACICYATHIDAE Bedford & Bedford, 1939

Genus AJACICYATHUS Bedford & Bedford, 1939

AJACICYATHUS NEVADENSIS (Okultich, 1943)

Pl. 11, fig. 7; Pl. 12, figs. 10,11; Pl. 14 fig. 6

This species is represented by numerous specimens from the Colville area, but by two only from the Salmo area. With the exception of one specimen, they are all smaller than the type i.e., 2 mm. in diameter as compared with 3 mm. Intervallum coefficient varies from 0.7 to 0.85 , in this respect agreeing well with the type intervallum coefficient of 0.8 to 1.0. The parietal coefficient varies

from 5 to 6.8, which is slightly higher than that of the type. This may be due to the small size of the specimens. Further growth could increase the diameter without increasing the number of parieties present. In substantiation of this, the specimen of greatest diameter has the lowest parietal coefficient.

Outer wall.—Thin to moderately thick in places, with numerous pores perforating, and partly perforating the wall. These latter pores are located in the thicker portions of the outer wall and may be upwardly inclined tubes.

Parieties.—Regularly arranged; usually straight, although some are gently curved; perforated by large pores; but many parieties are imperforate in thin-section, suggesting that the pores are widely spaced. Number of parieties varies from 10 to 13 where the diameter of the specimen is 2 mm.

Inner wall.—Stout, thick, simple; perforated by large pores.

Horizon and locality—Lower Cambrian at Colville, Stevens County, Washington; and on the south fork of the Salmo River at the base of the Laib Group, B.C. This species has previously been reported from Caborca, Northwestern Sonora, Mexico; Inyo County Calif.; Silver Peak, Nevada; the Purcell Range, British Columbia; and from the McDame area, British Columbia.

AJACICYATHUS RIMOUSKI Okulitch, 1943
Pl. 13, figs. 1–3

This species is well represented by several specimens from both the Colville and Salmo localities. In contrast to *A. nevadensis*, *A. rimouski* is more abundant in the collection from the Salmo area.

General shape.—*A. rimouski* resembles *A. nevadensis*, but differs in the number of parieties and relative width of the intervallum. The ratio of intervallum to diameter of central cavity varies from 1.1 to 1.4, and the parietal coefficient varies from 7.1 to 8.8.

Outer wall.—Moderately thick, simple; two or three large pores are intersept, such that pore area nearly equals area of skeletal material.

Parieties.—Numerous; straight, or gently curved; slender, long, rarely perforated by large pores, which tend to appear in the parieties close to the inner wall.

Inner wall.—Stout, thick, occasionally perforated by large pores.

Horizon and locality.—Lower Cambrian of

EXPLANATION OF PLATE 11

FIG. *1*—*Monocyathus* sp. Oblique transverse section illustrating single thick inner wall. U.B.C. Paleo. Coll. No. CL11d-22, ×13.0.

2–5,—*Archaeopharetra typica* Bedford & Bedford, *2*, oblique transverse section. Note coarse texture of skeletal tissue. U.B.C. Paleo. Coll. No. CL2d-1, ×7.5. *3*, oblique transverse section. U.B.C. Paleo. Coll. No. CO18a-1, ×8.2. *4*, transverse section. U.B.C. Paleo. Coll. No. CL3b-2, ×5.1. *5*, longitudinal section showing tendency of skeletal tissues to curve downward in central region of the cup. U.B.C. Paleo. Coll. No. CL2b-1, ×5.4.

6—*Claruscyathus solidus* Vologdin. Longitudinal section. Note upwardly curved tabulae, and coarsely perforated parieties. U.B.C. Paleo. Coll. No. CL11b-3, ×4.3.

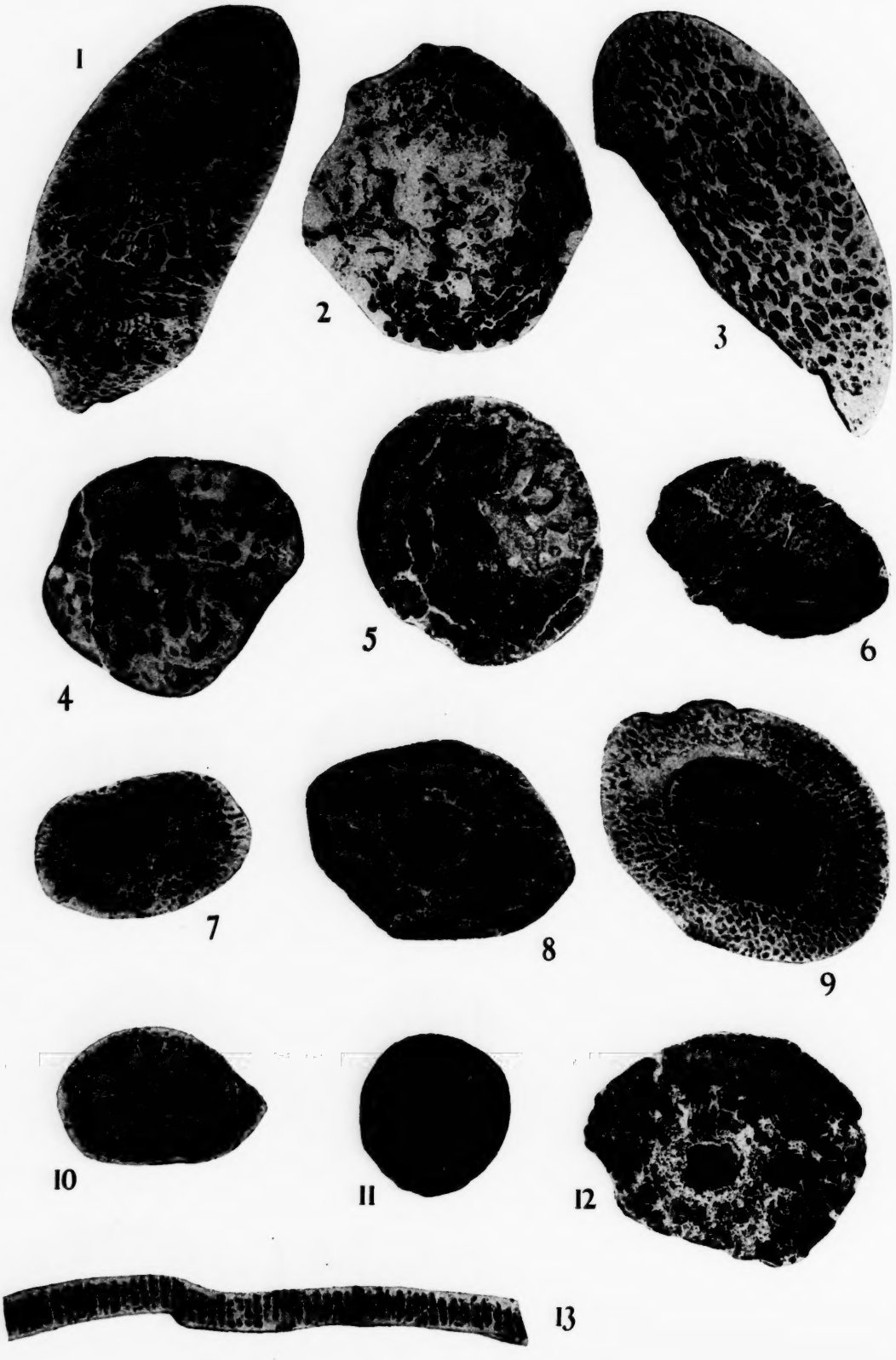
7—*Ajacicyathus nevadensis* (Okulitch). Transverse section showing simple walls and straight regular parieties. U.B.C. Paleo. Coll. No. CO17b-2, ×8.5

8,9—*Claruscyathus solidus* Vologdin *8*, transverse section illustrating thin tabulae and stout perforate parieties. U.B.C. Paleo. Coll. No. CL10b-4, ×5.4. *9*, Transverse section. U.B.C. Paleo. Coll. No. CL9b-6, ×5.4.

10—*Archaeosycon* sp. Transverse section. Poorly preserved specimen showing fine curved tabulae. U.B.C. Paleo. Coll. No. CL1a-2, ×4.6.

11,12—*Claruscyathus solidus* Vologdin. *11*, transverse section. U.B.C. Paleo. Coll. No. CL9b-9; ×4.9.*12*, oblique longitudinal section illustrating parieties and curved tabulae. U.B.C. Paleo. Coll. No. CL2d-7; ×4.9.

1
2
3
4
5
6
7
8
9
10
11
12


1
2
3
4
5
6
7
8
9
10
11
12
13

Colville, Washington, and on the south fork of the Salmo River. *A. rimouski* has been also reported from Caborca, Mexico; and from the type locality at Bic Harbour, Rimouski County, Quebec.

Genus ARCHAEOCYATHELLUS Ford, 1873
ARCHAEOCYATHELLUS sp.
Pl. 14, fig. 8

This species is represented by one very minute specimen from the Salmo locality. Preservation of this specimen is sufficiently good so that definite allocation to the genus *Archaeocyathellus* could be made. However, since the species are distinguished by pore pattern, not visible in the specimen, specific identification is impossible.

General shape.—Specimen was studied as a transverse section on a polished surface; slightly oval in section, diameters of 1 mm. and 0.6 mm.; intervallum about 0.2 mm. wide; central cavity 0.4 mm. in diameter; intervallum coefficient of 0.5; 11 parieties were counted in an average diameter of 0.8 mm., giving a parietal coefficient of 13.8.

Outer wall.—Longitudinally fluted, furrows coinciding with the junction of the parieties and the outer wall; pores not visible; thick; secondary calcification possible.

Parieties.—Short, stout, regularly arranged; imperforate.

Inner wall.—Not furrowed or fluted; pores not visible; thick.

Horizon and locality.—Lower Cambrian from the south fork of the Salmo River, B.C. Numerous other occurrences are cited in the literature: Rocky Mountain Cordillera; New York State, U.S.A.; Australia, Spain and Russia.

Family ETHMOPHYLLIDAE Okulitch, 1943
Genus ETHMOPHYLLUM Meek, 1868

The genus *Ethmophyllum* is well represented in the collections from the Colville and Salmo areas. The Salmo locality is especially abundant in specimens of the three species described below.

This genus is considered to be one of the most highly organized genera of the Archaeocyatha (Okulitch, Zhuravleva). The mathematical regularity observed in the arrangement of parities, the pore distribution in the outer wall, and the complex inner wall confirm this impression. As a result of this high degree of organization, and from

---

EXPLANATION OF PLATE 12

FIGS. *1–3*—*Protopharetra* sp. *1*, transverse section. Poorly preserved specimen illustrating fine irregular skeletal tissue. U.B.C. Paleo. Coll. No. CL20b–3, ×3. *2*, transverse section. U.B.C. Paleo. Coll. No. CL8a–4, ×3.4. *3*, oblique longitudinal section. Note mesh-like skeletal tissue. U.B.C. Paleo. Coll. No. CL4b–2, ×5.7.

4,5—*Protopharetra dunbari* Okulitch. *4*, transverse section. Stouter skeletal tissues than in *Protopharetra* sp. and very narrow central cavity. U.B.C. Paleo. Coll. No. CL7b–8, ×8.1. *5*, transverse section. Note narrow central cavity. U.B.C. Paleo. Coll. No. CL11a–6, ×9.3.

6—*Archaeocyathus borealis* Okulitch. Transverse section. Fragmental specimen illustrating wide intervallum. U.B.C. Paleo. Coll. No. CL20f–2, ×6.6.

7–9—*Archaeocyathus atlanticus* Billings. *7*, transverse section. Note well-defined inner wall and central cavity. U.B.C. Paleo. Coll. No. CL20c–3, ×6.6. *8*, ×7.3. transverse section. U.B.C. Paleo. Coll. No. CL20e–2, ×7.3. *9*, transverse section. Note wide central cavity and thick inner wall. U.B.C. Paleo. Coll. No. CL20c–2, ×5.

10, 11,—*Ajacicyathus nevadensis* (Okulitch). *10*, transverse section. Illustrates regular parieties and coarsely perforate inner wall. U.B.C. Paleo. Coll. No. CL11c–6, ×13.2. *11*, transverse section. U.B.C. Paleo. Coll. No. CL7b–7, ×13.1.

12—*Pycnoidocyathus columbianus* (Okulitch). Transverse section showing thin parieties perforate by large pores. U.B.C. Paleo. Coll. No. CL11a–11, ×2.8.

13—*Pycnoidocyathus* sp. Transverse section. Note short parieties and thin connecting dissepiments. U.B.C. Paleo. Coll. No. CO17b–6, ×5.

the findings of Zhuravleva (1955), the occurrence of *Ethmophyllum* is regarded as indicative of late Lower Cambrian horizons.

ETHMOPHYLLUM AMERICANUM
Okulitch, 1952
Pl. 13, fig. 11; Pl. 14, figs. 5,9,12

Only two specimens of this species are present in the collection from the Colville area, but it is a common species from the Salmo locality. It is easily distinguished from *E. whitneyi* by its very large central cavity, relatively narrow intervallum, and numerous parieties. The inner wall of *E. americanum* is usually slightly less complex than that of *E. whitneyi*.

In general shape, it is a long cone-like structure similar to other *Ethmophyllum* species. One incomplete specimen was 55 mm. long and 7 mm. in diameter at the larger end. The parietal coefficients of the specimens varied from 7.4 to 8.8; type specimen has parietal coefficient of 7.6. The intervallum coefficient was more variable, ranging from 0.18 to 0.4. This coefficient in the type material varies from 0.14 to 0.16.

Outer wall.—Moderately thick to thin; finely perforate by 3 to 4 pores per intersept in some specimens, 6 to 8 pores per intersept in others.

Parieties.—Numerous, short, stout; apparently imperforate; straight, simple.

Inner wall.—Complex, consisting of one row of shallow cup-like processes projecting into the central cavity; these processes appear to be arranged in vertical as well as horizontal rows; occasionally fragments of a smaller, secondary row are visible; perforated by coarse pores; skeletal material very thick in comparison with parieties and outer wall.

Horizon and locality.—From the Lower Cambrian of Sonora, Mexico, the type locality; and from the Lower Cambrian of Colville, Washington, and Salmo, B.C.

ETHMOPHYLLUM WHITNEYI Meek 1868
Pl. 13, figs. 7,8; Pl. 14, figs. 7,10

The collection of Archaeocyathids from the Salmo locality is rich in well-preserved specimens of this species. So prolific and numerous are they that the fauna is virtually dominated by them. *E. whitneyi* also occurs at the Colville locality, but to a very minor extent.

In general shape, *E. whitneyi* is slender, tapering and cone-like, with occasional annulations on the surface.

Outer wall.—Moderately thick; 4 to 6 slit-like pores per intersept, the number of pores being constant for any one specimen, but varying from specimen to specimen.

Parieties.—Numerous, short, thick elements; regularly arranged; 36 parieties in one specimen of 6 mm. diameter; very rarely perforated by pores, but occasionally pores do occur in the parieties near the inner wall.

Inner wall.—Complex arrangement in rows, one or two, of vesicles apparently derived from fusion and waving of the ends of parieties; in longitudinal section, vesicles appear to be attenuated cup-like projections opening upward; structural elements of the inner wall are stronger, stouter than those of the parieties or outer wall; occasional large pores perforate all inner wall components.

Horizon and locality.—*E. whitneyi* occurs in the Lower Cambrian at the South Forks of the Salmo River, B.C. and from the Colville area. Other North American localities are: Silver Peak District, Nevada; Inyo County, California; and Caborca, Mexico.

ETHMOPHYLLUM LINEATUS, n. sp.
Pl. 14, figs. 2–4

This new species is represented by seven specimens from the Salmo locality. All the specimens were studied in polished section. The species is characteristic of *Ethmophyllum* in possessing a complex inner wall, and fine, regularly arranged parieties, but atypical in its bowl-like conformation.

General shape.—A flattened, saucer-like form with a very narrow intervallum; the intervallum width varies from 1 mm. to 1.75 mm., with 2.4 to 2.8 parieties per millimeter. Since only fragmental specimens are available, the parietal and intervallum coefficients cannot be accurately determined. Estimates of these are: parietal coefficient—200:30, intervallum coefficient—1.5:27.

Outer wall.—Thin; perforated by 6 to 8 fine pores per intersept in some specimens, 9 to 11 in others.

Parieties.—Very short, straight, slender; numerous; apparently imperforate; slightly shorter than those of *E. americanum.*

Inner wall.—Complex, consisting of 1 to 2 rows of fine, narrow vesicles; the vesicles are similar to those of *E. whitneyi*, but with shorter diameters; perforate by occasional large pores; thick skeletal material composes the inner wall.

Horizon and locality.—Lower Cambrian at the South Forks of the Salmo River, near the International Boundary, in B.C.

Holotype.—University of British Columbia Paleontology Collection—No. SB-14; Geological Survey, Canada, No. 14315; *paratype*, University of British Columbia Paleontology Collection—No. SC-9. G. S.C. No. 14316.

Order METACYATHIDA Bedford & Bedford, 1936

Family ARCHAEOCYATHIDAE Taylor, 1910

Genus ARCHAEOCYATHUS Billings, 1861

This genus is very common in the Colville collection, but only two specimens of *Archaeocyathus* occur in material from the Salmo locality. The majority of the specimens, including the two from the Salmo collection, is referred to the species, *A. atlanticus.* This is a common species, being almost world-wide in distribution. One other species of *Archaeocyathus* described here is *A. borealis.* It is not well-represented in the collection from Colville, and is absent from the Salmo collection.

ARCHAEOCYATHUS ATLANTICUS Billings, 1861

Pl. 12, figs. 7–9; Pl. 14, fig. 11

This species is represented by numerous well-preserved specimens. They are particularly abundant in the Colville collection.

General shape.—Gently tapering, cone-like form; circular in transverse section, but occasionally showing minor undulations of the outer margin; diameters of the specimens range from 5.0 to 7.5 mm., with corresponding intervallum widths from 1.3 to 2.4 mm.; the central cavity diameters vary from 1.4 to 3.6 mm.; these measurements give an average intervallum coefficient of 0.65, the actual coefficients vary from 0.5 to 0.92. This variation in the intervallum coefficient is typical of the general variability of the species.

Outer wall.—Relatively thick; well-defined; perforated by numerous coarse pores; in transverse section these pores in some portions of the wall resemble canals; this appearance is due directly to the thick wall.

Intervallum.—Wide, filled by irregular skeletal tissue which forms the walls of very irregular curving canals; the whole intervallum resembles a closely knit mesh of tissue enclosing anastomosing, polygonal canals; the canal walls are perforate by abundant large pores.

Inner wall.—Of variable thickness, but thick even in the thinner portions; perforated at frequent intervals by large pores; these pores may represent the inner terminal ends of the intervallum canals opening into the central cavity.

Central cavity.—Moderately large; elliptical to circular in transverse section; contains no skeletal tissue.

Horizon and locality.—As previously stated, *A atlanticus* is an extremely common species. The more important localities are in Australia, Russia, Spain, and North America. In North America, *A. atlanticus* occurs in Lower Cambrian rocks of Labrador; Silver Peak, Nevada; the McDame area, Purcell Range, Aiken Lake area, and the Salmo area, of British Columbia; and in the Colville area, Washington.

ARCHAEOCYATHUS BOREALIS Okulitch, 1955

Pl. 12, fig. 6; Pl. 13 fig. 4

Two specimens from the Colville area represent this species. Both specimens appear as transverse sections; one is complete, the other has a portion of the outer wall and intervallum missing. Despite the scarcity of good specimens, the narrow central cavity, fine intervallum tissue, and thin outer wall characteristic of *A. borealis* are unmistakable. The specimens are quite small. The diameter of the larger is 5.0 mm., with a central cavity diameter of 1.0 mm. This yields an intervallum coefficient of 2.0, which differs only slightly from the type coefficient of 1.66.

Outer wall.—Appears as a thin film; perforated by numerous small pores.

Intervallum.—Very wide; similar to *A. atlanticus* in general appearance of skeletal tissues and canals, but differs in the finer and more delicate construction of the skeletal elements, and in the reduction in diameter of the canals; numerous small pores perforate the canal walls and other tissues of the intervallum.

Inner wall.—Relatively thin; perforated by frequent moderate sized pores; these perforations produce a ragged appearance, such that the intervallum tissues seem to protrude through the inner wall into the central cavity.

Central cavity.—Very narrow; well-defined; circular to elliptical in outline; clear of any skeletal elements.

Horizon and locality.—From the Lower Cambrian of the McDame area, British Columbia, and from the Colville area, Washington.

Order ARCHAEOPHYLLIDA
Okulitch, 1943
Family ARCHAEOPHYLLIDAE Vologdin, 1931
Genus ARCHAEOPHARETRA Bedford & Bedford, 1936
ARCHAEOPHARETRA TYPICA Bedford & Bedford 1936
Pl. 11, figs. 2–5

A problem exists in the precise distinction between the ontogeny of the genera *Archaeopharetra* and *Protopharetra*. The two genera resemble each other in their simplicity and lack of well-organized skeletal tissue. They differ in that *Archaeopharetra* lacks an inner wall and central cavity. Other differences are the imperforate tissues and generally smaller size of *Archaeopharetra* sp., particularly *A. typica*, and the development in *Protropharetra* of more pronounced mesh-like structures. It is still open to question, however, whether *Archaeopharetra* is a valid genus, or merely a variation in growth stages of *Protopharetra*. Differentiation of tissue into the poorly developed inner wall and central cavity characteristic of *Protopharetra* could be accomplished in *Archaeopharetra* by very minor changes in the skeletal structure. This organization could occur in the adult stage, with accompanying development of perforate walls and mesh-like structures to produce specimens identical to those of *Protopharetra*. This confusion in the ontogeny of *Archaeopharetra* and *Protopharetra* will be clarified only when abundant, perfect specimens of their various species are found. Until that time, it can only be suggested that they may be congeneric.

This is the first time specimens have been referred to *A. typica* since Bedford and Bedford described it in 1936. The species is represented by five well-preserved specimens from the Salmo locality. These were studied as thin-sections, four transverse and one longitudinal.

General shape.—A blunt, cone-like form; small; circular to elliptical in transverse section; specimens vary from 2.5 to 6 mm. in diameter; the specimen studied as a longitudinal section has a length of 15 mm., a greatest diameter of 2.5 mm. tapering down to a diameter of 1 mm.; annulations of the outer wall were observed in this longitudinal section.

Outer wall.—Thick; well-defined; imperforate.

Interior of cup.—No inner wall or central cavity; flattened, rounded bars more or less fill the cup; all skeletal structures in the cup are imperforate.

Horizon and locality.—Lower Cambrian of Colville, Washington; and Lower Cambrian of South Australia.

Remarks.—It was at first thought that the specimens designated as *A. typica* might well be referred to *Rhizacyathus radix*. However, on close examination of Bedford and Bedford's (1936, 1937, 1939) original descriptions and plates of these species, it was felt that they are actually conspecific. They differ only in that *Rhizacyathus radix* has slightly stouter skeletal structures than *A. typica*. This thickening could be caused by secondary calcification or by some minor environmental factor. Since *Archaeopharetra* has priority, the specimens are referred to this genus.

Genus PROTOPHARETRA Bornemann, 1886

Of all the Archaeocyathid genera from the Lower Cambrian of the Colville locality, *Protopharetra* is probably the most abundant in terms of actual number of specimens. This abundance of a simple, unspecialized genus

suggests that this zone is one of the lowermost Archaeocyathid horizons in the Cambrian. *Protopharetra* also occurs in the Lower Cambrian of the Salmo area but in fewer numbers.

PROTOPHARETRA DUNBARI Okulitch, 1943
Pl. 12, figs. 4,5; Pl. 14, fig. 1

Several specimens of this species occur in the collections from the Colville and Salmo localities. The specimens studied were transverse sections in polished rock fragments or in thin-sections. Preservation was excellent in most cases, although some secondary calcification had occurred, particularly in the outer walls.

General shape.—Almost circular in transverse section; diameters of the specimens varied from 3.0 mm. to 4.5 mm.; intervallum widths of 1.3 mm. to 1.9 mm., with corresponding central cavity diameters from 0.4 mm. to 0.6 mm., resulting in an average intervallum coefficient of 3.0.

Outer wall.—Relatively thick, spongy structure with a few large pores.

Intervallum.—Very wide; filled by a mesh of stout, perforate, anastomosing rods and curved bars, which form more or less complete lacunae. There is no decrease in the size of these cells near the inner wall, differing in this respect from similar structures in *Syringocnema*.

Inner wall.—Not clear or distinct in most specimens, but sufficient is observed to outline the central cavity; where present, the inner wall is thick and perforated by rare, large pores.

Central cavity.—Very narrow, circular in transverse section; not well-marked in most specimens.

Horizon and locality.—Found in the Lower Cambrian of Labrador; Inyo County, California; probably Aiken Lake area, B.C.; Salmo area, B.C.; and Colville area, Washington.

PROTOPHARETRA sp.
Pl. 12, figs. 1–3

This species includes a variety of *Protopharetra* forms which represent the bulk of the Archaeocyathid specimens from the Colville area. They exhibit the characteristics of the genus, and, in addition, some minor features that are not truly typical.

Only one specimen of this generalized *Protopharetra* species occurred in material from the Salmo River locality.

General shape.—The large number of thin sectioned specimens available show all views and orientations of the species. The cup varies in shape from turbinate to cylindrical; sometimes with an irregular outline, but generally circular. The specimens range from 3.5 mm. to 11.5 mm. in diameter, and from 9.0 to 30 mm. in length.

Outer wall.—Consistently thin, and finely perforate in all specimens; smooth outer surface; inner surface with rods and bars fused to it at irregular intervals.

Intervallum.—Wide; crossed by a thick, iregular mesh of bars, rods, and also in some specimens by curved, thin dissepimental tissue; in some, the mesh is very roughly organized into pariety-like structures; all the thick rods, bars, and pariety-like elements are perforated by coarse, large pores; the dissepimental tissues are never perforated.

Inner wall.—Poorly developed or absent in nearly all specimens; in others, the inner wall is formed by fusion of bars and rods.

Central cavity.—Completely absent, or an ill-defined zone in the center of the cup where skeletal tissue is absent or scarce.

Horizon and locality.—*Protopharetra* is a very cosmopolitan genus. It has been reported from the Lower Cambrian of Spain, Sardinia, Russia, Australia, and North America. *Protopharetra* sp., as described above, occurs in the Lower Cambrian rocks of Colville area, Washington, and from the Salmo area, B.C.

Family PYCNOIDOCYATHIDAE
Okulitch, 1950
Genus PYCNOIDOCYATHUS Taylor, 1910
PYCNOIDOCYATHUS COLUMBIANUS
(Okulitch, 1943)
Pl. 12, fig. 12; Pl. 13, figs. 12,14

This common species of the northern Cordilleran geosyncline is represented in the Colville collection by two specimens: a transverse section and an oblique longitudinal section. None of the specimens from the

Salmo locality can be assigned, with any certainty, to this species.

General shape.—A short, turbinate cone; occasional transverse annulations; circular in transverse section; largest specimen is 15 mm. in diameter; width of central cavity, 5.5 mm., giving an intervallum coefficient of 0.71, which is slightly larger than that of the type.

Outer wall.—Thin; perforated by numerous, fine pores; partially replaced in both specimens by brown argillaceous material.

Intervallum.—Wide; crossed by fairly regular parieties carrying synapticulae and dissepiments; numerous, large pores perforate the parieties; 30 parieties occur in a diameter of 15 mm., yielding a parietal coefficient of 2.0.

Inner wall.—Not well-preserved in the transverse section, and, of course, not visible at all in the oblique longitudinal section; apparently rather thin, and perforated by large pores.

Central cavity.—Wide; well-defined, and free of skeletal tissue.

Horizon and locality.—Reported from Lower Cambrian rocks of the Dogtooth Range, and from the McDame area of British Columbia, and from Colville, Washington.

PYCNOIDOCYATHUS AMOURENSIS (Okulitch, 1943)
Pl. 13, figs. 9,10

Several poorly preserved specimens from the Colville and Salmo collections are referred to this species. These specimens resemble the type in the development of a narrow central cavity, a wide intervallum filled with numerous, fairly regular, stout, perforate parieties, and in the presence of short dissepiments and synapticulae. No accurate estimates of the intervallum and parietal coefficients can be made since the outer walls have been either replaced by argillaceous material, or removed by fracturing of the rock.

Outer wall.—Absent in all specimens, except for a small portion in one specimen; moderately thick; finely perforate.

Intervallim.—Wide; contains numerous, coarsely perforate parieties crossed by dissepiments and synapticulae.

Inner wall.—Well-defined; perforated by small pores.

Horizon and locality.—*P. amourensis* is known from the Lower Cambrian of Labrador, at Point Amour and Taylor's Gulch; McDame area, B.C., and from the Dogtooth Range, near Golden, B.C. The specimens described above occur in rocks of Lower Cambrian age from Salmo, B.C., and from Colville, Washington.

PYCNOIDOCYATHUS sp.
Pl. 12, fig. 13

The single specimen of this species was found in a fairly pure, white, crystalline limestone fragment from the Colville locality.

In general shape, the specimen is long, attenuated, and saucer-like. From estimations of the curvature of the incomplete specimen, this saucer may have been from 10 to 12 cms. in diameter. Parietal and intervallum coefficients are relatively meaningless for specimens with this shape, but the number of intersepts per millimeter is a useful ratio. In this specimen there are approximately three parieties per millimeter. The total length, in transverse section, of the specimen is over 2.6 cms.; the width is constant at 1.5 mm.

Outer wall.—Fairly thick; simple; appears perforate by large pores.

Intervallum.—Extremely narrow; crossed by very short, numerous parieties, which are perforated by abundant, medium-sized pores; the parieties are joined by short, thin, curved dissepiments and occasional synapticulae; in general, the parieties are more regular, and better defined than is typical of *Pycnoidocyathus.*

Inner wall.—Thick; perforated by numerous, large pores.

Central cavity.—This is not visible as such, but must have been very large and wide. The area of the slide that corresponds to the central cavity is covered by many small specimens of other Archaeocyathids.

Remarks.—*P.* sp. appears to be related to *Pycnoidocyathus* in much the same manner as *Ajacicyathus undulatus* is to *Ajacicyathus.* Both species possess saucer-like shapes with numerous short parieties, very narrow intervallums, and wide central cavities. *P.* sp.

differs from *Ajacicyathus undulatus* in the development of synapticulae and dissepiments; otherwise the two species are very similar.

Horizon and locality.—From the Lower Cambrian of the Colville area, Washington.

Genus DENDROCYATHUS Okulitch & Roots, 1947
DENDROCYATHUS sp.

Only one fragmental specimen of this genus was found in material from the Colville locality. The specimen is a segment of a transverse section comprising the outer wall, intervallum and the entire inner wall and central cavity. Diameter of the complete specimen was probably 3.5 mm.

General shape.—Circular in transverse section, presumably a conical, cup-like form.

Outer wall.—Smooth exterior; thick; coarsely perforate.

Intervallum.—Wide, approximately four times wider than the central cavity; crossed by numerous, complex parieties which branch from inner to outer wall; parieties appear bead-like in transverse section because of the many large pores; no synapticulae or taenia typical of the genotype, *D. unexpectans*, are present.

Inner wall.—Thick, perforated by medium-sized pores.

Central cavity.—Very narrow; elliptical in transverse section; free of any skeletal tissue.

Horizon and locality.—From the Lower Cambrian of Colville, Washington. Genotype is from the Lower Cambrian of Aiken Lake area, B.C.

Family METACOSCINIDAE Bedford & Bedford, 1936
Genus ARCHAEOSYCON Taylor, 1910
ARCHAEOSYCON sp.
Pl. 11, fig. 10

Two specimens from the Colville collection are tentatively assigned to this genus. Positive identification cannot be made since both specimens are oblique longitudinal sections that do not show the inner wall and central cavity. Tentative identification is based on the occurrence of convex, perforate tabulae; porous, loosely arranged parieties; and the presence of some vesicular tissue in the remaining open spaces.

General shape.—Cylindrical, with transverse annulations occurring 4 to 5 mm. apart; length of incomplete specimen, 17 mm.; diameter of same specimen, 5 to 6.5 mm.

Outer wall.—Thick, coarsely perforate; partially removed from both specimens.

Intervallum.—Numerous thick parieties; parieties appear as rows of bead-like elements, a result of numerous coarse pores; fine, rarely perforate, downward (?) arching tabulae occur in both specimens; tabulae are fairly numerous; vesicular tissue partially fills the central area of one specimen.

Inner wall.—Not visible.

Horizon and locality.—Lower Cambrian of Colville, Washington; and the type locality of L'Anse au Loup, Labrador.

Genus CLARUSCYATHUS Vologdin, 1932
CLARUSCYATHUS SOLIDUS Vologdin, 1937
Pl. 11, figs. 8,9,11–12

More than thirty specimens have been identified as *C. solidus*, all from the Lower Cambrian of Colville, Washington. This species was first reported by Vologdin (1932) from Middle Cambrian rocks of Siberia. Zhuravleva (1955) has since shown this to be erroneous, and the Siberian strata in question are actually of Lower Cambrian age.

General shape.—Irregularly shaped, but in general a cylindrical form; one specimen measured 30 mm. in length with a diameter of 8 mm.

Outer wall.—Thick, irregular in outline; perforate.

Intervallum.—Very wide; numerous, fairly well-defined, coarsely perforate parieties; the numerous tabulae are relatively thin, perforate, and appear to be upwardly convex, but difficult to be certain of this since the irregular shape of the specimens renders it difficult to determine with precision their orientation; the central cavity is not well-defined, but merely a zone where skeletal structures are absent.

Horizon and locality.—Lower Cambrian of Colville, Washington. This is the first report

of this species from North America. Other localities are in Siberia and Antarctica.

Order SYRINGOCNEMIDA
Okulitch, 1935
Family SYRINGOCNEMATIDAE Taylor, 1910
Genus SYRINGOCNEMA Taylor, 1910
SYRINGOCNEMA COLVILLENSIS, n. sp.
Pl. 13, figs. 5,6

This species is represented by two transverse views in thin-section from the Colville collection. Both specimens are well preserved, except that the outer wall and portions of the intervallum of one specimen have been removed by fracturing of the rock. Despite the lack of a longitudinal section, there is no difficulty in definitely identifying the specimens as belonging to a new species of *Syringocnema*. The characteristic tube-filled intervallum, the relatively large size of these tubes, and the narrow central cavity are the main distinguishing features of the species.

General shape.—Other *Syringocnema* species possess a long cone-like form, and in the absence of longitudinal sections, it is assumed that this species has a similar shape. In transverse section, the outer margin of the cup is deeply indented or crenulated, about 20 crenulations occurring in a diameter of 5 mm. Both specimens are roughly elliptical in section with diameters of 5.5 mm. and 3.5 mm. Width of intervallum varies from 1.3 mm. to 2.6 mm. in the type specimen, with a diameter of 0.9 mm. This yields an average intervallum coefficient of 2.5. In comparison, the intervallum coefficient of the genotype, *S. favus*, is 0.75.

Outer wall.—Thick; irregular outline; apparently perforated by coarse pores, which are probably the constricted ends of the tube-like cells of the intervallum.

Intervallum.—Very wide; well-defined; bridged from outer to inner wall by long, polygonal, tube-like cells; these cells are inclined gently downwards from the outer to inner wall, but curve sharply down in the vicinity of the inner wall; in transverse section, this cell structure appears as elongated, narrow cells near the outer wall, shorter, narrow cells in the central parts of the intervallum, and at the inner wall the cells be-

EXPLANATION OF PLATE 13

FIGS. *1–3*—*Ajacicyathus rimouski* Okulitch. *1*, transverse section. Note abundant parieties. U.B.C. Paleo. Coll. No. CL6b–7, ×13.2. *2*, transverse section of poorly preserved specimen. U.B.C. Paleo. Coll. No. CL7b–3, ×12.4. *3:* transverse section. U.B.C. Paleo. Coll. No. CL3a–2, ×13.1.

4—*Archaeocyathus borealis* Okulitch. Transverse section. Note wide intervallum, fine loculi. U.B.C. Paleo. Coll. No. CL3a–2, ×6.4.

5, 6—*Syringocnema colvillensis*, n. sp. *5*, transverse section. Illustrates wide intervallum, thick inner wall. Paratype. U.B.C. Paleo. Coll. No. CO18b–1, ×10. *6*, transverse section. Holotype. U.B.C. Paleo. Coll. No. CL2a–1, ×7.5.

7, 8—*Ethmophyllum whitneyi* Meek. *7*, oblique transverse section. Note complex inner wall, and slit-like pores of the outer wall. U.B.C. Paleo. Coll. No. CL10b–6, ×1.01. *8*, oblique transverse section. U.B.C. Paleo. Coll. No. CL5a–2, ×10.7.

9, 10, *Pycnoidocyathus amourensis* (Okulitch). *9*, transverse section. Outer wall corroded. U.B.C. Paleo. Coll. No. CL11e–6, ×7.4. *10*, transverse section. U.B.C. Paleo. Coll. No. CL11b–1, ×6.

11—*Ethmophyllum americanum* Okulitch. Transverse section illustrating the wide central cavity and narrow intervallum. U.B.C. Paleo. Coll. No. CL20e–9, ×5.2.

12—*Pycnoidocyathus* sp. cf. *P. columbianus*. Longitudinal section, slightly oblique. Note elliptical pores of inner wall. U.B.C. Paleo. Coll. No. CL12a–2. ×2.4.

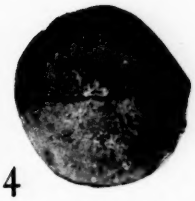
13—*Syringocyathus* sp. Oblique longitudinal section. Note downward and inwardly inclined tubes in the intervallum. U.B.C. Paleo. Coll. No. CL20e–2, ×4.2.

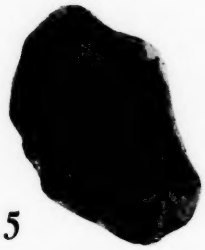
14—*Pycnoidocyathus* sp. cf. *P. columbianus*. Longitudinal section. Illustrates horn-like shape of complete cup. U.B.C. Paleo. Coll. No. CL11c–7, ×2.4.

1

2

3


4

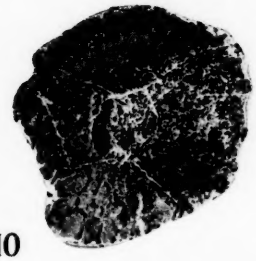

5

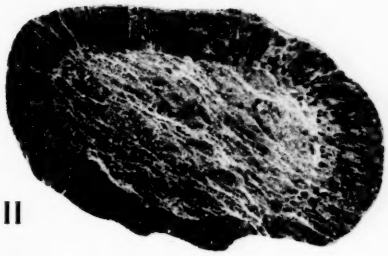
6

7

8

9

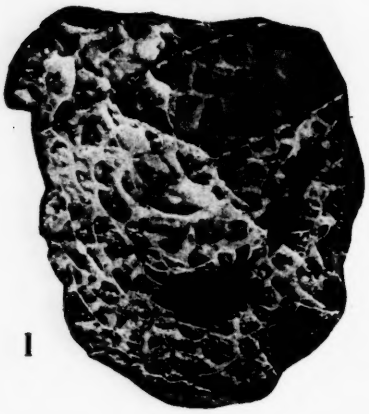

10


11

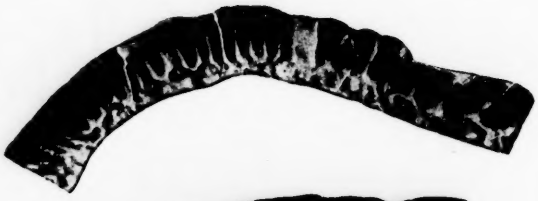
12

13

14



1

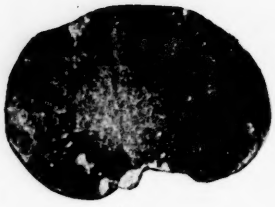


2

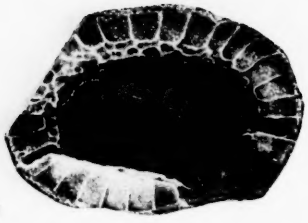
3

4

5



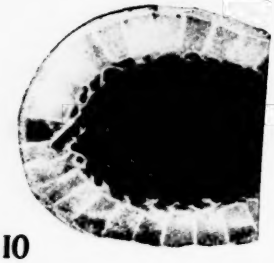
6



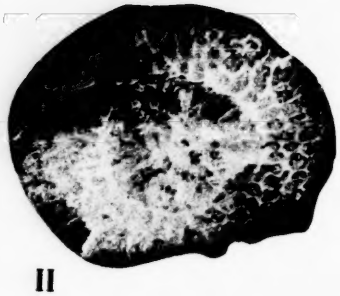
7

8

9



10



11

12

come abruptly polygonal and considerably smaller; diameters of the tube-like cells decrease from 0.3 mm. at the outer wall to 0.1 mm. at the inner wall; all cells are perforated by occasional large pores.

Inner wall.—Thick; well-defined; perforated by abundant large pores; as in the outer wall, this is probably a result of the penetration of the inner wall by the tube cells.

Central cavity.—Narrow; circular, even when outer margin of cup is elliptical; free of any skeletal tissue.

Horizon and locality.—From the Old Dominion formation, Lower Cambrian of the Colville area, Washington.

Remarks.—Syringocnema colvillensis, n. sp., differs from *S. favus* in the possession of a considerably narrower central cavity, and coarser, fewer tube cells in the intervallum. It is similar to *S. eleganta* and *S. minuta* in the polygonal shape of the tube cells, but has coarser textured intervallum structures.

Holotype.—University of British Columbia Paleontology Collection No. CL2a–l. G.S.C. No. 14317; *paratype*, University of British Columbia Paleontology Collection No. CO18b–l. G.S.C. No. 14318.

Genus SYRINGOCYATHUS Vologdin, 1937

SYRINGOCYATHUS CANADENSIS Okulitch, 1955

One specimen of this species was discovered in the Salmo material. The precise identification of the specimen was made possible by exposure of both transverse and longitudinal views on polished surfaces. The longitudinal section was slightly oblique, but sufficiently centered to show the inner wall and central cavity.

General shape.—Cylindrical, tapering; smooth exterior; greatest diameter, 6.6 mm.; length, 12 mm.; intervallum width, 1.4 mm., and diameter of central cavity, 1.0 mm., thus an intervallum coefficient of 1.5. This agrees well with the type intervallum coefficient i.e. 1.3.

Outer wall.—Thick, spongy; perforated by numerous, large coarse pores.

Intervallum.—Relatively wide; filled by upward and outwardly inclined tubes or pipes, producing a coarse honeycomb effect in transverse section; the tubes are inclined at an angle of 30° with the axis of the cup, and vary in diameter from 0.2 to 0.3 mm.; all tube walls are perforated by coarse pores.

Inner wall.—Thick; coarsely perforated

EXPLANATION OF PLATE 14

FIG. *1*—*Protopharetra dunbari* Okulitch. Oblique transverse section. Note irregular mesh-like tissue. U.B.C. Paleo. Coll. No. SC–6, ×4.

2–4—*Ethmophyllum lineatus*, n. sp. *2*, transverse section. Illustrates complex inner wall, short parieties, and attenuated form of the species. U.B.C. Paleo. Coll. No. SC–9. Holotype, ×6.1. *3*, transverse section. U.B.C. Paleo. Coll. No. SB–14. Paratype, ×6.7. *4*, transverse section. U.B.C. Paleo. Coll. No. SE–1, ×6.3.

5—*Ethmophyllum americanum* Okulitch. Transverse section. U.B.C. Paleo. Coll. No. SC–7, ×5.7.

6—*Ajacicyathus nevadensis* (Okulitch). Transverse section, illustrating fine, regular parieties. U.B.C. Paleo. Coll. No. SB–4, ×8.7.

7—*Ethmophyllum whitneyi* Meek. Transverse section. U.B.C. Paleo. Coll. No. SK–1, ×5.4.

8—*Archaeocyathellus* sp. Transverse section, showing longitudinal furrows of outer wall. U.B.C. Paleo. Coll. No. SC–14a, ×5.5.

9—*Ethmophyllum sp. E. cf. americanum* Okulitch. Longitudinal section. Portion of specimen illustrates shelf-like projections of the inner wall. U.B.C. Paleo. Coll. No. SC–12, ×5.7.

10—*Ethmophyllum whitneyi* Meek. Transverse section. U.B.C. Paleo. Coll. No. SA–10, ×6.4.

11—*Archaeocyathus atlanticus* Billings. Transverse section. U.B.C. Paleo. Coll. No. SB–7, ×5.5.

12—*Ethmophyllum* sp. cf. *E. americanum* Okulitch. Transverse section. Wider central cavity than is typical of *E. americanum*. U.B.C. Paleo. Coll. No. SK–3, ×3.7.

by terminations of the inclined tubes.

Central cavity.—Narrow; clear of vesicular tissue; tendency to be elliptical in transverse section.

Horizon and locality.—The type specimen is reported from the Lower Cambrian of the McDame area, B.C. The specimen described above is from the south fork of the Salmo River, B.C.

SYRINGOCYATHUS sp.
Pl. 13, fig. 13

One of the specimens of *Syringocyathus* from the Colville area differs slightly from the previous species described. The differences are in the intervallum coefficient, and the angle between the inclined tubes and the cup axis. In all other respects, the specimen is very similar to *S. canadensis.* Since the species is only represented by one fragmental longitudinal section, it is not recorded as a new species. Further study of *Syringocyathus* may, in fact, show this specimen to be a variation of *S. canadensis.*

General shape.—Elongated, tubular cup; smooth exterior; intervallum width variable, but generally about 1.75 mm., central cavity diameter of 2.5 mm., thus an intervallum coefficient of 0.9; length of fragment, 20 mm.

Outer wall.—Thick, perforated by inclined tubes; very similar to *S. canadensis.*

Intervallum.—Narrow; crossed by upwardly inclined tubes, the angle between the tubes and the cup axis varying from 45° to 50°, in contrast to the 30° angle in *S. canadensis;* tube diameters vary from 0.2 to 0.3 mm.; the tube walls are perforated by coarse pores.

Inner wall.—Thick; perforated by large pores, the terminal ends of the inclined tubes.

Central cavity.—Wide; free of any skeletal tissue.

Horizon and locality.—From the Lower Cambrian of Colville, Washington.

BIBLIOGRAPHY

BEDFORD, R. & BEDFORD, J., 1936, Further notes on Cyathospongia from the Lower Cambrian of Beltana, South Australia: Kyancutta Museum Mem. 3, p. 21–26.

——, 1937*a*, Anatomy and classification of the Cyathospongia (Archaeos) from the Lower Cambrian of Beltana, South Australia: mimeographed copy, p. 1–11.

——, 1937*b*, Further notes on Archaeos (Pleospongia) from the Lower Cambrian of South Australia: Kyancutta Museum Mem. 4, p. 27–38.

——, 1939, Development and classification of Archaeos (Pleospongia): Kyancutta Museum Mem. 6, p. 67–82.

BEDFORD, R., & BEDFORD, W. R., 1934, New species of Archaeocyathinae and other organisms from the Lower Cambrian of Beltana, South Australia: Kyancutta Museum Mem. 1, p. 1–7.

BILLINGS, E., 1861, New species of Lower Silurian fossils, Pt. 1: Geol. Survey Canada, p. 5.

BORNEMANN, J. G., 1886, Die Versteinerungen des Cambrischen Schichtensystems der Insel Sardinien: Nova Acta den kals—Leop.-Carol deutchen Akad. der Naturforscher, Band 51, 1, p. 28–78.

CAMPBELL, C. D., 1947, Cambrian rocks of northeastern Stevens County, Washington: Geol. Soc. America Bull., v. 58, p. 597–613.

COOPER, G. A. *et al*, 1952, Cambrian stratigraphy and paleontology near Caborca, Northwestern Sonora, Mexico: Smithsonian Misc. Coll., v. 119, no. 1, p. 1–23,27–35.

FORD, S. W., 1873*a*, On some new species of fossils from the Primordial or Potsdam Group of Rensselaer County; New York (Lower Potsdam): Am. Jour. Sci., ser. 3, v. 5, p. 211–213.

LITTLE, H. W., 1950, Salmo map area, B.C.: Geol. Survey Canada, Paper 50–19.

MEEK, F. B., 1868, Preliminary notice of a remarkable new genus of corals, probably typical of a new family: Am. Jour. Sci., ser. 2, v. 45, p. 62–64.

——, 1886, Note on *Ethmophyllum* and *Archaeocyathus*: Am. Jour. Sci., ser. 2, v. 46, p. 144.

OKULITCH, V. J., 1935, Cyathospongia—a new class of Porifera to include the Archaeocyathinae: Roy. Soc. Canada, trans., ser. 3, sec. 4, v. 29, p. 75–103.

——, 1937, Change in nomenclature of Archaeocyatha: Jour. Paleontology, v. 11, no. 3, p. 251.

——, 1940, Revision of type Pleospongia from Eastern Canada: Roy. Soc. Canada, ser. 3, sect. 4, v. 34.

——, 1943, North American Pleospongia: Geol. Soc. America, Spec. Paper No. 48, p. 55–107.

——, 1950, Nomenclature notes on Archaeocyatha: Jour. Paleontology, v. 24, no. 3, p. 392–395.

——, 1951, A Lower Cambrian fossil locality near Addy, Washington: *ibid.*, v. 25, no. 3, p. 405–407.

——, 1955*b*, Treatise on Invertebrate Paleontology: Geol. Soc. America, vol. E.

OKULITCH, V. J., & GREGGS, R. G., 1958, Archaeocyathid localities in Washington, British Columbia, and the Yukon Territory: Jour. Paleontology, v. 32, no. 3, p. 617–623.

OKULITCH, V. J., & ROOTS, E. E., 1947, Lower Cambrian fossils from Aiken Lake Area,

British Columbia: Roy. Soc. Canada, Trans., ser. 3, sect. 4, v. 41, p. 37–46.

TAYLOR, T. G., 1910, The Archaeocyatha from the Cambrian of South Australia: Mem. Roy. Soc. South Australia, v. 2, pt. 2.

VOLOGDIN, A. G., 1931, Archaeocyatha of Siberia, Pt. 1. Faunas of the limestone of Ulus Bei-Buluk and Kameshki Village, Minusinsk Region, and of Nijnaya Ters River, Kuznetsk district: United Geol. Prosp. Survey, U.S.S.R., p. 1–119.

——, 1932, Archaeocyathinae of Siberia, Pt. 2. Fossils of the Cambrian limestones of Altai Mountains: United Geol. Prosp. Survey, U.S.S.R., p. 1–106.

——, 1934, On the Archaeocyathi from the basin of the Laba River in North Caucasus: Contr. Acad. Sci. U.S.S.R., v. 4, no. 8–9, p. 500–505.

WALCOTT, C. D., 1887, Note on the genus *Archaeocyathus* of Billings: Amer. Jour. Sci., ser. 3, v. 34, p. 145–146.

ZHURAVLEVA, I. T., 1954*a*, Archaeocyatha of the Siberian Platform and their significance to the stratigraphy of the Cambrian of Siberia: Contr. Acad. Sci. U.S.S.R., v. 1, p. 484–493.

——, 1954*b*, Information on the study and collection of Archaeocyatha: Contr. Acad. Sci. U.S.S.R., v. 5, p. 3–51.

ZHURAVLEVA, I. T., & KORDE, K. B., 1955, Further notes on the Archaeocyatha of Siberia: Contr. Acad. Sci. U.S.S.R., v. 104, no. 3, p. 474–477.

ZHURAVLEVA, I. T., & ZELENOV, K. K., 1955, On the bioherms of the multicoloured Suite of the Lena River: Contr. Acad. Sci. U.S.S.R., v. 56, p. 57–77.

MANUSCRIPT RECEIVED JULY 26, 1958.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 76–80, PL. 15, 1 TEXT-FIG., JANUARY 1959

A NEW OCCURRENCE OF DEVONIAN RADIOLARIA IN CALCAREOUS CONCRETIONS OF THE HURON MEMBER OF THE OHIO SHALE

HELEN P. FOREMAN
131 South Professor Street, Oberlin, Ohio

ABSTRACT—A new occurrence of well-preserved Devonian Radiolaria in calcareous concretions of the Huron member of the Ohio shale is described. The Radiolaria, consisting primarily of Spumellina with some Nassellina present, are compared with other known Devonian radiolarian assemblages.

INTRODUCTION

SOME years ago while Dr. Fred Foreman was making a study of the calcareous concretions in the Huron member of the Ohio shale from Milan, Ohio, he found abundant well preserved Radiolaria within the concretions. It is the purpose of this preliminary paper to record and describe this remarkable fauna. A thorough taxonomic study will follow.

The writer is indebted to Dr. Fred Foreman for suggesting this study and for collecting and preparing the material.

LOCALITIES

Concretions in the Huron member of the Ohio shale and its extension south in Kentucky and north in Canada were collected from Berea in central Kentucky north through Ohio to Kettle Point, Ontario (see text-fig. 1).

The greatest number of concretions were obtained from northern Ohio near Milan and Norwalk. Forty were studied. Here Radiolaria were found in concretions of all sizes from small and spherical, 4 to 5 inches in diameter, to very large, 11 feet in diameter. The large concretions usually appear as slightly flattened spheres. The concretions from this area showed the greatest concentrations of Radiolaria. One specimen from Norwalk had Radiolaria concentrated in bands 3 centimeters thick. Generally, however, the Radiolaria are in much thinner bands. One concretion (see pl. 15, fig. 7) from Milan showed three bands of concentrated Radiolaria 5 millimeters thick and many narrower bands, some as little as 0.5 millimeter. Spores and sponge spicules were generally present and in only one of the forty specimens studied from this locality were there no Radiolaria and no siliceous material.

Concretions collected from the southernmost locality, Berea, Kentucky, were small, lenticular, about $2\frac{1}{2}$ by 1 inch, to spherical, about $1\frac{1}{2}$ inch in diameter, and when etched in hydrochloric acid did not present the banded appearance that is so striking in the larger concretions examined further north. No Radiolaria were found, although spores and fragments of carbonized material were abundant. Small round pellets of porous chalcedony were common. Often this material filled the spore cases and the pellets may have derived their shape from being molded inside other spore cases no longer present. The alternative that they are poorly preserved spumelline Radiolaria has been considered, but no structure was observed to support this theory. Of the five concretions from Berea only one displayed a pyritized border, another showed a small coral along its border along with various shaped holes that indicated other fossil material may once have been present.

Further north one concretion was examined from Vanceburg, Kentucky. After etching, this concretion appeared finely granular with thin bands, 0.5 millimeter wide, of light siliceous material separated by bands of darker clay minerals varying in width from 2.0 to 5.0 millimeters. Poorly preserved Radiolaria and spores were scattered throughout the concretion, but along and near the siliceous bands the Radiolaria were slightly more numerous. The only other fossil found was one sponge spicule.

Not until concretions were examined from Sinking Springs in southern Ohio about 25 miles north of Vanceburg were good speci-

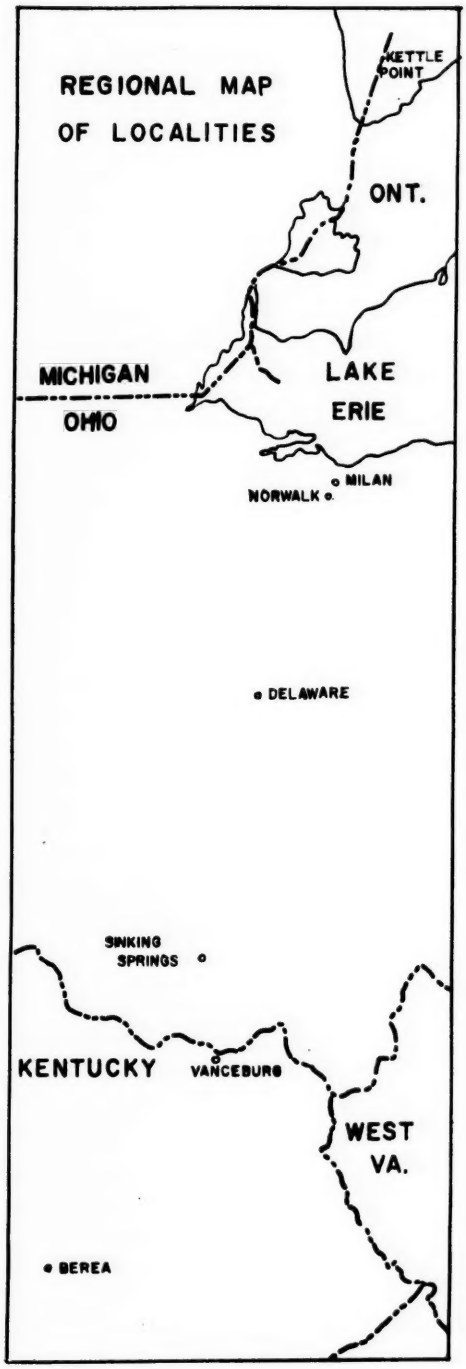
mens of Radiolaria found. These concretions were larger, varying in size from 4 inches up to 5 feet, and spherical to lenticular in shape. Of five concretions examined two contained well preserved Radiolaria concentrated in distinct bands up to 2.0 millimeters thick; scattered Radiolaria were present throughout. These two concretions were small, about 6 inches in diameter, with a well-defined pyritized border. No Radiolaria were found in the other three concretions. One of these was small with a well pyritized border, the other two are fragments from the larger concretions. All five contained spores.

In central Ohio concretions were collected along the Olentangy River about 6 miles north of Delaware. Four of the five concretions studied contained Radiolaria concentrated in bands from less than 0.5 to 1.5 millimeters thick. Radiolaria and spores were also scattered throughout.

North from Milan and Norwalk, along the strike of the outcrop of the Huron shale, is the well known calcareous concretion locality of Kettle Point, Ontario. These concretions were fully described by Daly (1900). Unfortunately this site was not visited and only one sample, a fragment from a large concretion supplied by Dr. G. F. Caley, was available for study. After treatment this sample showed many spores, but no Radiolaria. The negative result from the study of this one sample should, however, not be taken to preclude the presence of Radiolaria in concretions from this locality.

PREPARATION

The concretions were prepared by cutting slices about 1 to 2 centimeters thick and then etching them in a bath of dilute hydrochloric acid. Some slices were disintegrated by the acid treatment to leave a structureless residue of clay and silt, porous white silica, pyrite, spores, and Radiolaria. Others were etched but maintained their form; these were the ones high in silica, clay, and pyrite. After washing, the etched slice or the residue from complete etching was examined under a stereomicroscope and individual specimens were collected for further study. Solution and secondary deposition of the silica had, of course, altered and obscured some of the structures of the Radio-



TEXT-FIG. *1*—Regional map showing localities from which concretions were collected.

laria. However, some extraordinarily good specimens could be found.

Because of the fragile structure of these Radiolaria the fine needles and brushes generally used for picking microfossils proved unsatisfactory. A simple device made of one human hair attached to a stick with a bit of tape, the hair extending about one centimeter beyond the stick with the root end free, proved an excellent picking tool. This pick had the double advantage of flexibility, preventing damage to the delicate structures of the Radiolaria, and only a little adhesiveness from the slight roughness of the root end of the hair so that there was no difficulty in disengaging the specimen once it was picked up.

RADIOLARIA

The system of classification followed is that of Campbell (1954) based primarily on the early work by Haeckel (1887*a*).

Kinds.—Most of the Radiolaria in this fauna belong to the suborder Spumellina. The remainder belong in the suborder Nassellina. The spumelline fauna consists almost entirely of Liosphaericae (spherical). There are a few Ellipsidiicae (elliptical), but up to the present time no Cenodiscicae (discoidal or lenticular) or Laracariicae (lentelliptical) have been observed. Among the Liosphaericae are many Cubosphaeridae (six spines at right angles). The Nassellina are represented primarily by members of the simplest division, the Plectellari (incomplete skeleton), but there are also a very few rare Cyrtellari (complete lattice shell).

Description.—The fauna is characterized by its delicate nature. The lattice-shelled Spumellina have thin pore bars, many fine by-spines, which are generally broken, giving a burr-like effect to the specimens, and strong main spines when these are present. The spongy Spumellina, although they give the appearance of being sturdier, have a delicate lattice under the spongy surface and the latter is itself made up of a very fine meshwork.

The Spumellina range in size as follows: few of the specimens examined were smaller than 0.1 millimeter, and many were in the range 0.125 to 0.2 millimeter; two common genera were as large as 0.4 millimeter; and complete main spines as long as 0.4 millimeter were measured.

The Nassellina are very fragile and because the majority are simple Plectellari, whose branching structure of spines gives less strength than the basic sphere of the Spumellina, they are poorly preserved and generally appear as fragments. The very rare Cyrtellari are also mostly fragmentary.

An unusual feature of the Spumellina in this fauna is the joining of the radial beams within the medullary or the single lattice shell of some forms. This joining has been most frequently observed in the Cubosphaeridae, where the radial beams meet off-center in two groups of three connected by a short bar. This meeting of the radial beams was described by Hinde (1899, p. 46, 48, 49, 51) in five of the forty-six spumelline species he described from the Devonian of Tamworth, New South Wales, Australia. The off-center meeting of the radial beams is emphasized in the Cubosphaeridae when the main spines, which are the outer extensions of the radial beams, continue to be off-center as they leave the lattice shell. This structure would seem to confirm Popofsky's earlier speculations (1912, p. 81) as to the phylogenetic background of present-day Radiolaria. He proposed the joining of two simple four-rayed spicules to form the skeletal framework about which the lattice shell and from which the projection of main spines would develop. The earliest spined form then would be a six-spined Cubosphaeridae with the four-spined Staurosphaeridae developing later as one set of main spines atrophied. This theory would account for the complete lack of Staurosphaeridae in this fauna and also in the Devonian fauna from Europe, described by Rüst (1891–92), but not for the presence of seven Staurosphaeridae and the absence of Cubosphaeridae in the fauna described by Hinde (1899, p. 46–47).

Popofsky (1912, p. 89–90) figured two modern forms from the south polar seas with six extremely fine radial beams extending from six main spines and meeting in the center. The author, too, has seen modern forms with this same internal structure, which were very kindly supplied by Dr. Robert Bieri from a Lamont Geological Laboratory sample taken in the Caribbean. The

relation of these fossil and modern radial beams to the phylogenetic development of Radiolaria is an interesting problem that the author hopes to pursue in a further study.

Comparison with other Devonian faunas.—The predominance of spumelline forms agrees with other studies of Paleozoic Radiolaria, where they are by far the most common form. Specifically this fauna seems to have closer affinities to that described by Hinde (1899) from Tamworth, Australia, than either that of Aberdeen (1940) in the Caballos formation of Texas or that of Rüst (1891–92) from the South Ural Mountains and from Germany.

Similarities to the Tamworth fauna of Hinde include the large number of forms with thin shells, small pores, and heavy main spines; the joining of the radial beams inside the innermost lattice of some forms; and the presence of simple nasselline forms belonging to the Plectellari. However, the complete lack of Cubosphaeridae and abundant Staurosphaeridae in the Tamworth fauna does provide a striking difference.

The presence of nasselline forms belonging to the Cyrtellari while extremely rare in this fauna were entirely absent from those described by Hinde and Aberdeen. Rüst recorded seventeen genera belonging to the Cyrtellari in his report. In North America the only other Paleozoic Cyrtellari are three genera, described as rare, from New York cherts of Ordovician age (Ruedemann & Wilson, 1936, p. 1564).

Manner and conditions of occurrence.—Banding was usually the most prominent feature of those concretion slices that did not disintegrate in the acid bath. These bands were either of white silica or clay material and always horizontal, paralleling as nearly as could be observed the general bedding of the shale outside of the concretion, although the bedding planes of the shale immediately surrounding the concretion generally curved above and below it. The white silica bands in some concretions were made up almost entirely of well-preserved Radiolaria, in others solution and redeposition had so altered the Radiolaria that few structures beyond their spherical form were discernible and in still others no radiolarian structures at all were visible. The bands themselves varied in width from less than 1 to 30 millimeters. These differences are due no doubt to radiolarian tests accumulating in varying amounts and undergoing varying degrees of solution. Outside the bands isolated Radiolaria are often found.

Of all the concretions examined only two, one from the Olentangy River locality north of Delaware and one from Milan, contained no siliceous material whatsoever, although there were many holes, round, tubelike, and crescent-shaped, which may be fossil molds. A definite banding effect was caused by the variations in size and color of the clay minerals, and the holes while scattered throughout were more numerous along the darker bands. This type of banded material with alternating dark and light layers appears to be similar to that discussed by Bradley (1931, p. 319–328) and described as varves, with the dark bands representing organic material deposited at the end of the seasonal peak of life in the seas in which these sediments were laid down. Whether this interpretation could be carried over to the type of concretion in which the Radiolaria occur abundantly is problematical. As in these the bands of Radiolaria aside from being horizontal do not appear in any uniform order in relation to the mineral material that remains after etching. Sometimes the bands of Radiolaria occur under such a band of clay minerals and sometimes over, and sometimes the etching of the carbonate material leaves them standing completely alone. Generally the concretions containing abundant Radiolaria also are high in carbonate.

In the surrounding shales conodonts, algae, flattened spores, phosphatic brachiopods belonging to the Lingulacea, and occasional carbonized plant fragments are found. It would seem, however, that pressure and leaching have removed all trace of the Radiolaria that surely were laid down at one time in the shales outside the concretions as well as within them.

This association of Paleozoic Radiolaria with plant fragments is not unique. Prof. T. W. E. David & Mr. E. F. Pittman(1899, p. 27), in describing the radiolarian rocks of New South Wales, from which the aforementioned fauna described by Hinde was derived, found abundant plant remains associated with the Radiolaria in the shale

and concluded (p. 36) that "the radiolaria were deposited in clear sea-water, which, though sufficiently far from land to be beyond the reach of any but the finest sediment, was nevertheless not of very considerable depth." The presence of phosphatic brachiopods belonging to the Lingulacea would also, according to Cooper (1957, p. 265), indicate an environment of shallow water for these shales. To this evidence may now be added the evidence of the Radiolaria. The forms with delicate shells have in the past (Haeckel, 1887*b*, p. 129) and (Aberdeen, 1940, p. 131–132) been taken as an indication of pelagic types living on or near the surface of the sea. This together with the absence of large heavy-shelled forms associated with cold and deep water would indicate an environment of shallow water for this fauna and further strengthen the evidence for shallow water deposition of this phase of the Huron shale.

LITERATURE CITED

ABERDEEN, ESTHER, 1940, Radiolarian fauna of the Caballos formation, Marathon Basin, Texas: Jour. Paleontology, v. 14, p. 127–139, pls. 20,21, text-figs. 1,2.

BRADLEY, W. H., 1931, Non-Glacial marine varves: Am. Jour. Sci., 5th ser., v. 222, no. 130, p. 318–330.

CAMPBELL, A. S., 1954, Radiolaria, *in* CAMPBELL, A. S. & MOORE, R. C., Protista *3* (chiefly Radiolarians and Tintinnines): Treatise on Invertebrate Paleontology, R. C. Moore, editor, Part D, p. 11–163, text-figs. 6–86, Lawrence, Kansas, Univ. Kansas Press and Geol. Soc. America.

COOPER, G. A., 1957, Paleoecology of Middle Devonian of eastern and central United States, *in* LADD, H. S., editor, Treatise on marine ecology and paleoecology, v. 2: Geol. Soc. America, mem. 67, p. 249–278, 1 pl., 2 text-figs.

DALY, R. A., 1900, The calcareous concretions of Kettle Point, Lambton County, Ontario: Jour. Geology, v. 8, no. 2, p. 135–150.

DAVID, T. W. E., & PITTMAN, E. F., 1899, On the Paleozoic radiolarian rocks of New South Wales: Geol. Soc. London, Quart. Jour., v. 55, p. 16–37, pls. 2–7.

HAECKEL, ERNST, 1887*a*, Report on the Radiolaria collected by H. M. S. Challenger during the years 1873–76: Rept. Voyage Challenger, Zoology, v. 18, cxxxvii+1893 p., 140 pls., 1 map.

——, 1887*b*, Die Radiolarien (Rhizopoda Radiaria) Eine Monographie, v. 2, 248 p., 64 pls., 1 map.

HINDE, G. J., 1899, On the Radiolaria in the Devonian rocks of New South Wales: Geol. Soc. London, Quart. Jour., v. 55, p. 38–63, pls. 8,9.

POPOFSKY, A., 1912, Die Sphaerellarien des warmwasser Gebiets der Deutschen Südpolar-Expedition 1901–1903: Bd. 13 (Zool. Bd. 5), p. 75–159, pls. 1–8, text-figs. 1–77.

RUEDEMANN, RUDOLPH, & WILSON, T. Y., 1936, Eastern New York Ordovician cherts: Geol. Soc. America, Bull., v. 47, p. 1535–1586, pls. 1–7, text-figs. 1,2.

RÜST, R. D., 1891–1892, Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen der Trias und der palaeozoischen Schichten: Palaeontographica, v. 38, p. 107–200, pls. 6–30.

MANUSCRIPT RECEIVED MAY 4, 1958.

EXPLANATION OF PLATE 15

FIGS. *1,3,4*—Spumelline Radiolaria. *1*, *Hexalonchidium* sp. Haeckel, cross section of medullary lattice showing meeting of radial beams, ×250; *3*, *Hexastylus* sp. Haeckel, ×220; *4*, *Hexacontium* sp. Haeckel, inner cortical and medullary shell showing meeting of radial beams, outer cortical shell missing, ×85.

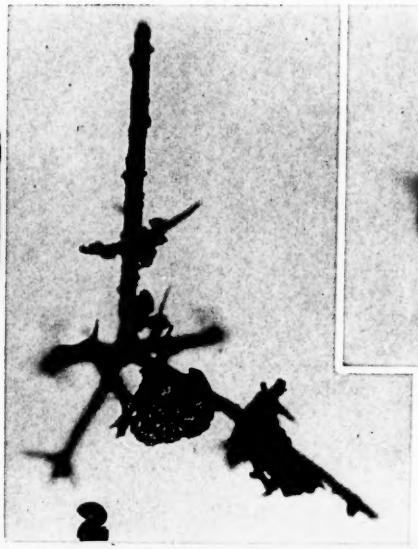
2—Nasselline Radiolaria. *Hexaplagia* sp. Haeckel, ×120.

5—Enlargement of section of concretion slice after etching, showing Radiolaria in place.

6—Concretion in place on south shore of Lake Erie, showing relation to shale.

7—Concretion slice after etching, showing pyrite border and Radiolaria in horizontal bands, Milan, Ohio.

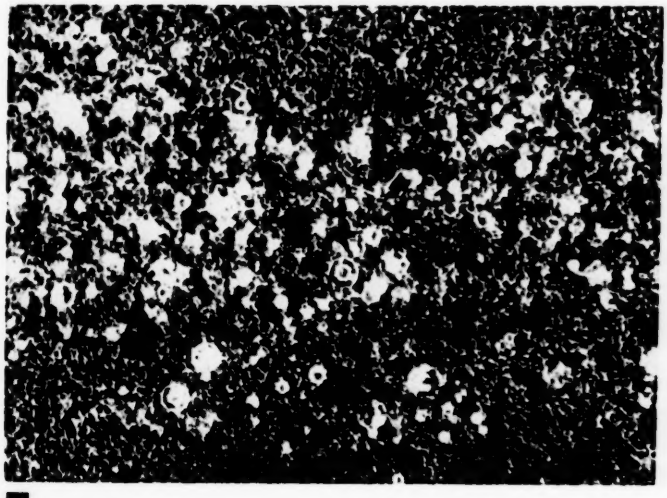
1



2

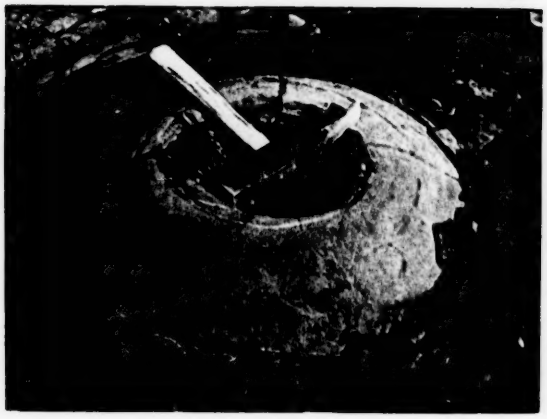
3

4

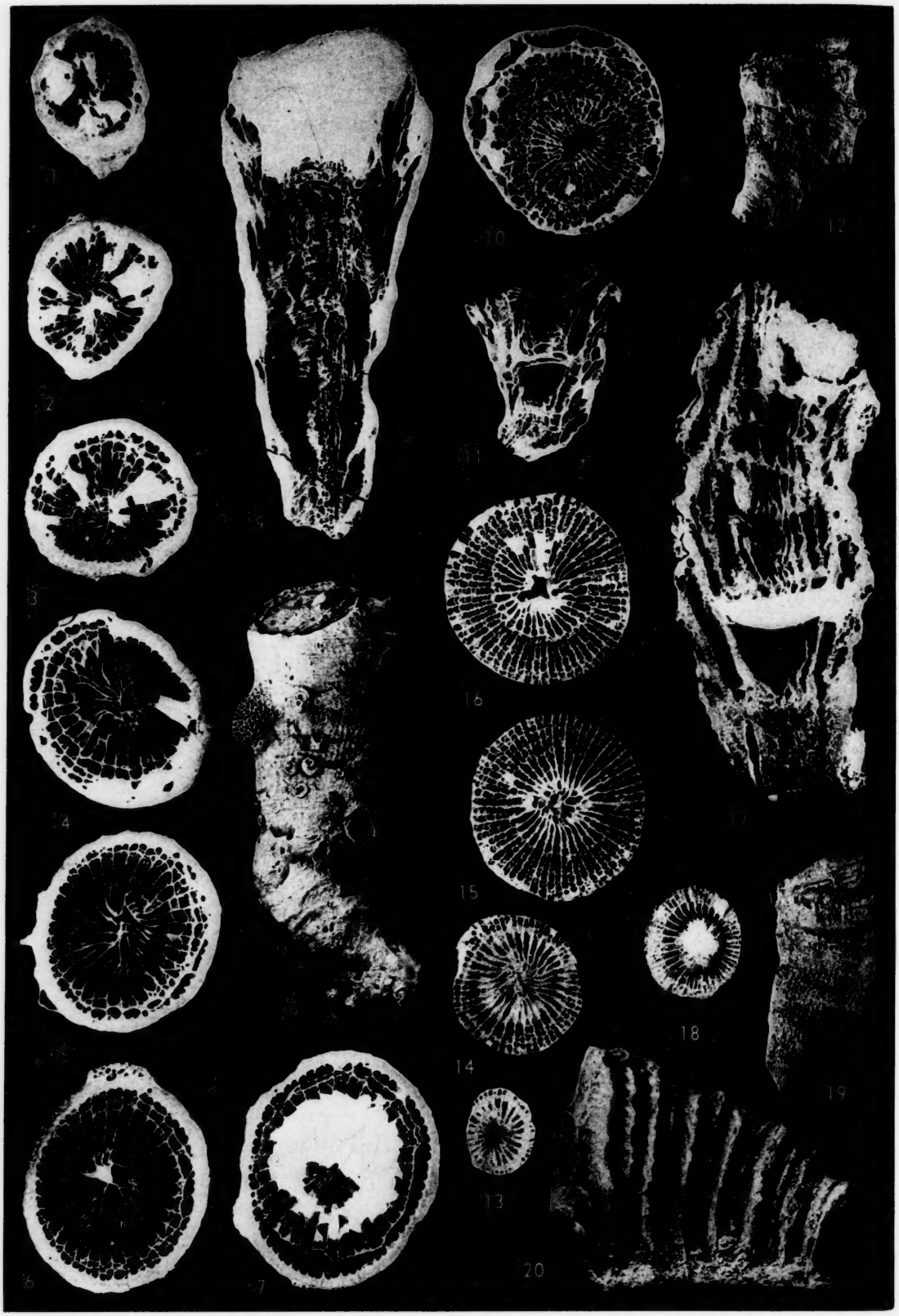


5

6



7


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 81–82, PL. 16, JANUARY 1959

ON THE IDENTITY OF THE DEVONIAN RUGOSE CORAL GENUS *DIVERSOPHYLLUM* WITH *TABULOPHYLLUM*, AND NOTES ON THE GENUS *CHARACTOPHYLLUM*

J. LLOYD WATKINS
Midwestern University, Wichita Falls, Texas

ABSTRACT—The Devonian rugose coral genus *Diversophyllum* is placed in synonymy with *Tabulophyllum*. Characters of the poorly understood genus *Charactophyllum* are described and illustrated.

INTRODUCTION

IN 1924 Carroll Lane Fenton & Mildred Adams Fenton described *Tabulophyllum*, a new genus of tetracoral, from the Upper Devonian Hackberry group of Iowa. They placed eleven new species in the genus and indicated that *Zaphrentis traversensis* Winchell was a species of this genus. In 1939 Laurence L. Sloss selected *Z. traversensis* as the type species of his new genus *Diversophyllum*. In this paper evidence is presented which suggests that *Diversophyllum* is a synonym of *Tabulophyllum*. All figured specimens are catalogued in the University of Michigan Museum of Paleontology.

SYSTEMATIC DESCRIPTIONS

Phylum COELENTERATA
Class ANTHOZOA
Subclass ZOANTHARIA
Order RUGOSA

Genus TABULOPHYLLUM Fenton & Fenton

Pl. 16, figs. 1–12

Tabulophyllum FENTON & FENTON, 1924, p. 30.
Diversophyllum SLOSS, 1939, p. 65–66.

Type species.—*Tabulophyllum rectum* Fenton & Fenton, 1924 p. 31, pl. 6, figs. 8–12.

Generic diagnosis (condensed from original description).—Coral small to large, solitary, irregularly turbinate, or subcylindrical. Calyx shallow to deep, typically flattened or slightly elevated at the bottom; fossula very weak or lacking; septa heavy, strong, alternating, non-carinate; primaries extending almost to center. Tabulae incomplete; vesicular area commonly well defined; dissepiments small to large.

Remarks.—Examination of sections of the type species revealed that the secondary septa are absent in the youthful stage and are represented as septal spines or crests on dissepiments in the mature stage (pl. 16, fig. 10). The dissepimentarium is lonsdaleioid, composed of numerous subglobose to elongate dissepiments. The tabularium is wide and consists of many complete or incomplete tabulae that form flat-topped domes.

Remarks on synonymy.—Serial sections of a topotypic specimen of *Tabulophyllum*

EXPLANATION OF PLATE 16

(Exteriors ×1 and sections ×1.5, unless otherwise indicated.)

FIGS. *1–9*—*Tabulophyllum traversensis* (Winchell). Serial sections and side view of hypotype no. 35449, lower blue shale of Gravel Point formation, quarry of the Petoskey Portland Cement Co., Petoskey, Emmet Co., Mich.

10–12—*Tabulophyllum rectum* Fenton & Fenton. *10,11*, transverse and longitudinal sections of hypotype no. 26340, Hackberry group, Rockford, Iowa; *12*, side view of holotype no. 7834, *Spirifer* zone of Hackberry group, Hackberry Grove, Iowa.

13–20—*Charactophyllum nanum* (Hall & Whitfield). *13–16*, serial sections of hypotype no. 35450; *17*, longitudinal section of hypotype no. 35451; *18,19*, plan and side view of hypotype no. 35452; *20*, enlargement of part of calyx of hypotype no. 35453, ×7. Specimens from the Hackberry group, Rockford, Iowa.

traversensis are illustrated (pl. 16, figs. 1–7). This species possesses all the structures that are characteristic of the genus *Tabulophyllum* (compare figures 7 and 10).

Conclusions.—Study of several dozen serial sections of topotypic specimens of the type species of *Tabulophyllum* and *Diversophyllum* indicates that both species have similar internal structures. *Diversophyllum* is here placed in synonymy with *Tabulophyllum.*

Genus CHARACTOPHYLLUM Simpson
Pl. 16, figs. 13–20

Charactophyllum SIMPSON, 1900, p. 209–210, fig. 28.

Type species.—*Campophyllum nanum* Hall & Whitfield, 1873, p. 232.

Description.—Corallites small, length ranging from 36 to 60 mm., diameter from 13 to 25 mm.; trochoid to turbinate; calyx 6 to 15 mm. deep, broad; fossula absent; septa about 60, primaries extending almost to center, secondaries about one-half as long, denticulate and faintly carinate (pl. 16, fig. 20); primaries dilated in immature stage, dilation confined to axial region in mature stage; carinae horizontal, typically very faint in transverse sections and not visible in longitudinal sections; tabularium wide; tabulae horizontal, flat-topped domes, or arched, complete or incomplete. Dissepimentarium well developed; small dissepiments numerous, globose, becoming elongate axially.

Remarks.—In 1872 Hall & Whitfield described *Campophyllum nanum* from the Hackberry beds of the Upper Devonian Hackberry group of Iowa as having strongly denticulate septa. In 1900 Simpson chose this species as the type for his new genus *Charactophyllum* and described the septa as being carinate and denticulate. Fenton & Fenton (1924) stated that the septa were strong, alternating, and denticulate. In 1949 Stanley Smith described the species as having long, amplexoid, axially dilated carinated septa. Dorothy Hill (1956) characterized the species as being small, solitary, with moderately dilated and carinate septa widely withdrawn from the axis.

The above descriptions are based on specimens of *Charactophyllum nanum* from the Hackberry group of Iowa. Since the characters of the genus are so poorly understood, an attempt is made to describe accurately the features of the type species.

Occurrence.—*Charactophyllum nanum* occurs only in the beds of the Upper Devonian Hackberry group of Iowa.

Types.—Hypotypes nos. 35450–35453.

BIBLIOGRAPHY

FENTON, C. L., & FENTON, M. A., 1924, The stratigraphy and fauna of the Hackberry Stage of the Upper Devonian: Contr. Mus. Geology, Univ. Mich., v. 1, p. xii+260, pls. i–xlv.

HALL, JAMES, & WHITFIELD, R. P., 1873, Descriptions of new species of fossils from the Devonian rocks of Iowa: 23rd. Ann. Rept. N. Y. State Cabinet Nat. History, p. 223–239, pls. ix–xii. Albany.

HILL, DOROTHY, 1956, Treatise on Invertebrate Paleontology, Part F, Coelenterata, Rugosa, University of Kansas Press.

SIMPSON, G. B., 1900, Preliminary description of new genera of Paleozoic rugose corals: Bull. N. Y. State Mus., v. 8, (39), p. 199–222.

SLOSS, L. L., 1939, Devonian rugose corals from the Traverse beds of Michigan: Jour. Paleontology, v. 13, no. 1, p. 52–73, pls. ix–xii.

SMITH, STANLEY, 1949, Upper Devonian corals of the Mackenzie River region, Canada: Geol. Soc. America, Special Paper no. 59, 84 p, pls. 1–35.

WINCHELL, A., 1866, The Grand Traverse region: Dr. Chase's Steam Printing House, Ann Arbor, Mich., p. 83–97.

MANUSCRIPT RECEIVED JUNE 2, 1958.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 83–98, PLS. 17,18, 8 TEXT-FIGS., JANUARY 1959

A PALEOECOLOGIC AND BIOMETRIC STUDY OF THE MIDDLE CAMBRIAN TRILOBITE *ELRATHIA KINGII* (MEEK)

ROBERT C. BRIGHT
University of Utah

ABSTRACT—This paper presents the results of a study of 339 complete specimens of the Middle Cambrian trilobite *Elrathia kingii* (Meek) from the Wheeler formation. The following descriptive addenda were noted: (1) granulosity is variable within the species, (2) the normal number of thoracic segments in adults is thirteen, but may vary from 10 to 13, (3) the pygidium has only four axial segments, and (4) the proximal thoracic "nodes" noted by Meek proved not to be part of the thoracic segment structure but secondary features resulting from a fracture along an inherently weak zone at the dorsal furrow.

Almost all the specimens have fibrous calcite incrustations on their ventral surface. A study of this unique preservation shows the cone-in-cone nature of the calcite and that its formation was partly controlled by the fossil carapace. Suggestions as to the origin of the calcite and its structure are noted.

Reconstruction of the Wheeler environment based on faunal and lithologic evidence indicates one of moderately shallow (<600′) calm water below wave base.

The single species is treated statistically in detail. Various structural relationships were plotted graphically and the appropriate data computed. The use of simple ratios as a taxonomic and descriptive tool is discussed and evidence presented to indicate that they are adequately utilized only when considered in light of total life of the trilobite plus their variance.

INTRODUCTION

TOPOTYPE material of *Elrathia kingii* (Meek), 1870, has been accumulating at the University of Utah for many years; from which the writer selected most of the 339 complete specimens for this study. In addition, the collection contains several hundred complete individuals too poorly preserved for accurate measurement, plus literally thousands of fragmentary remains. Many of the specimens were collected by the writer at the beginning of this study.

Of considerable interest, aside from the trilobites themselves, were the calcite incrustations, their origin, bearing on ecology, relationship to the fossilization of the organisms, and why they are rarely present on the dorsal surface of the carapace.

The synonymy and history of *E. kingii* are adequately discussed by Palmer (1954, p. 78) and need not be reiterated here.

All figured specimens, plus those used in the quantitative analysis, are in the paleontological collection of the Geology Museum, University of Utah.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Dr. W. L. Stokes, University of Utah, for suggesting the problem and for his assistance in seeing it to the present form. Dr. C. M. Woolf, Department of Genetics and Cytology, University of Utah, deserves special thanks for assistance and interest in the preparation of the statistical section of the report. My thanks also to Drs. A. B. Shaw, A. R. Palmer, and B. H. Burma for their helpful criticisms and suggestions. Funds for completion of the research were provided in part by the University Research Committee, University of Utah, to whom I extend my appreciation.

LOCALITY

The sample population described herein was collected from the type section of the Wheeler formation. The section is located in the Wheeler Amphitheater, which lies about five miles north of the eastern entrance to Marjum Pass and one-half mile southeast of Antelope Springs, House Range, Millard County, Utah. It was from this famed collecting locality that Meek (1870, p. 63) described *E. kingii* along with several other trilobites and brachiopods. Later, Walcott visited the area, collected additional specimens, and described the now classic House Range Cambrian section (1908*a*, p. 9–12). The area has been a favorite with both amateur and professional collectors alike since

before the turn of the century, for the magnificent fauna is easily collected, well-preserved, and the area is readily accessible by automobile.

STRATIGRAPHY

The Wheeler formation is underlain by the Swasey limestone, which, excluding the lower Condor member, "consists of dark- and black-gray, medium grained, massive and irregular bedded limestone" (Deiss, 1938, p. 1146). The upper Swasey limestones grade rapidly into the overlying Wheeler shales.

Walcott (1908*a*, p. 9–12) originally described the Wheeler formation from its occurrence in the Wheeler Amphitheater. Later (1908*b*, p. 181), he presented a better description of a section near the top of Marjum Pass as follows: "Alternating bands of thin, shaly limestone and calcareous shale, with shale gradually increasing and predominating toward the lower portion. At 405 feet from the top a band of blue-gray, hard limestone, in layers one-eighth to 2 inches thick occurs. At 473 feet another band, and below an occasional thin layer." He reported a thickness of 570 feet. Deiss (1938, p. 1067) emended Walcott's description thus:

> ". . . consists of dull sooty black, fine-grained, hard, platy and, rarely, fissile calcareous shale, which weathers pale-gray and contains numerous intercalated argillaceous and finely arenaceous platy limestones which increase upwards."

Wheeler (1948, p. 40) generally concurred with Deiss and gave a thickness of 350 feet for the shales.

The overlying Marjum limestone "is a dark gray, argillaceous, fine-grained, thin-bedded limestone with sooty-gray to almost black, fissile and platy calcareous irregularly bedded shale" (Wheeler & Steele, 1951, p. 36).

Lithologic equivalents of the Wheeler formation are known at the Leppy Range, northwestern Utah; and the Promontory Range, north-central Utah. A few miles north of the Leppy Range, in Crater Island (part of the Silver Island Mountains) the shales and siltstones grade laterally into a friable sandstone (Fred Schaefer, personal communication). Elsewhere (Pioche, Sheep-rock Range, and Wah Wah Range), equivalents are predominately limestones. The writer examined the section in the Sheep-rock Range and found it to consist of thin-bedded and laminated, fine-grained, dense, dark gray limestones, with light tan silt partings. It is noteworthy that the numerous specimens of *Peronopsis interstrictus* and *Elrathia* sp. rarely occur in the limestones, but rather in the silt partings.

FAUNAL LIST FOR WHEELER FORMATION

PORIFERA
- *Protospongia* sp.

BRACHIOPODA
- *Acrothele subsidua* (White)
- *Acrotreta attenuata* Meek
- *Obolus mcconnelli pelias* Walcott

ARTHROPODA

TRILOBITA
- *Agnostus bidens* Meek
- *Asaphiscus wheeleri* Meek
- *Bolaspidella housensis* (Walcott)
- *Chancia* sp.
- *Elrathia kingii* (Meek)
- *Elrathina cordillerae* (Rominger)
- *Olenoides nevadensis* (Meek)
- *Peronopsis interstrictus* (White)
- *Zacanthoides* sp.

MALACOSTRACA
- *Pseudoarctolepis sharpi* Brooks & Caster

ECHINODERMATA
- Eocrinoid—complete crown—gen. and sp. undet.

The fauna is middle Middle Cambrian in age.

OCCURRENCE

Walcott (1908*b*, p. 181) stated: "Many hundred trilobites, entire and backed by 'cone-in-cone,' have been picked up on the surface of the clay, resulting from the disintegration of the shales." The lower two-thirds of the formation is by far the more prolific. Near the bottom (50–100 feet above the base), *Peronopsis interstrictus* occurs in great profusion. Between 100 to 350 feet from the base, *E. kingii* is present in fantastic numbers.

The horizons bearing the most *E. kingii* are not true shales, but light- to medium-gray and light-tan calcareous siltstones (indeed, most of the so-called shales are siltstones). These siltstones break up readily when wetted (many of them immediately disintegrate upon contact with water) and, as a result of their disintegration, the calcite incrusted trilobites are left on and in the surface silts by the thousands. The fossils are quickly identified by their oval shape

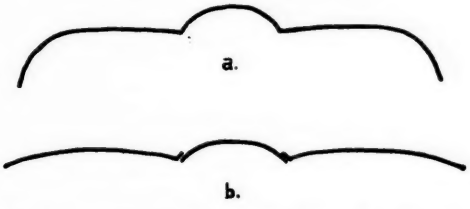
and size. The most abundant yielding sites are in the wash which fills small sidehill gullies formed by torrential rains.

DESCRIPTIVE ADDENDA

In addition to the characteristics noted by Meek (1870, p. 63) and those by Palmer (1954, p. 78), several new observations emerged from the present study, some of which may shed more light on variation within the species. (1) About 5 percent of the individuals exhibit various degrees of granulosity. The smallest specimen studied (3.1 mm.) (pl. 17, fig. 1) possesses minute granules concentrated principally on the cephalon. The largest specimen on which they were noted is 32.2 mm. long. The granules seem to be mainly developed on the cephalon, to a lesser degree on the thorax, and none were noted on the pygidium; 95 percent of the equally well-preserved individuals studied do not show granulosity. Those exhibiting granulosity were collected from several different horizons. It is thus apparent that granulosity for this species may vary within narrow limits. (2) The great majority of the adult individuals possess 13 thoracic segments. However, eight of some 400 specimens have 12 segments, one has 11, and one has but 10. Again, as in the case of the granulosity, these few specimens are otherwise identical to the majority and occur at different horizons. This indicates that the number of thoracic segments may vary slightly in *E. kingii*. Rasetti (1951, pp. 215, 221) noticed variation in the allied ptychoparioid genera *Elrathina* and *Chancia*. (3) Meek (1870, p. 64) noted the pygidium showed " . . . more or less distinctly about five segments." It seems, however, that the "fifth" segment is a product of crushing during preservation. All the individuals well enough preserved to exhibit the separate segments possess only four. The fourth, or terminal segment, is about twice as long as the preceding three, but is often crushed so that it appears as two. The posterior-end of the terminal segment consistently appears as a small ridge, lip, or platform which may overhang posteriorly. In addition, it is usually crushed to form a depression generally not involving the third segment. The combination of the lip or platform behind the depression accounts for the double appearance. (4) Regarding the thoracic segments, Meek (1870, p. 64) observed " . . . each with a small node or prominence at each end. (In some specimens these nodes seem to be wanting, while in others they do not exist on all of the segments.)" At the outset of the investigation these "nodes" were a problem. Why do some possess them and others not, while many are characterized by "nodes" on several segments but not on the remainder (pl. 17). This seemed contrary to the other narrow variations within the species.

Attempts to make thin sections perpendicular to the axis to interpret the structure proved futile, as the carapace was too soft and broke from the grinding. However, polished serial sections revealed enough to prove that the structure is not a feature of the test itself but the result of fractures paralleling the axis. The fractures always occur in the same position—at the distal margin of the axial segment, just above the bottom of the dorsal furrow (text-fig. 1). The fracture, as noted previously, may occur on all or several of the segments and on either side of the axis. When the fracture runs the length of the thorax, it often extends across the posterior limb as far forward as the posterior end of the palpebral lobe (p. 17, figs. 6,10). After fracturing, the separated pleuron moved slightly upward and inward to effect a small overlap, thence, cemented in the position shown in text-fig. 1b.

These same structures also appear in specimens of both *Asaphiscus* and *Elrathina* from the Wheeler formation. They are rarely present in *Elrathia* or *Elrathina* in areas where the Wheeler equivalent is a limestone. Numerous individuals from the Spence



TEXT-FIG. *1*—a, cross section of axis showing original shape of carapace. b, cross section of axis showing the shape of the carapace after flattening and relative movement of the freed pleura.

shale and some illustrated by Rasetti (1951, pl. 20, figs. 17,19; pl. 26, figs. 6–9; pl. 30, figs. 1–10) from British Columbia shales exhibit these same structures. The writer has seen very few of these fractures in any of the trilobites from limestones in either the House Range, Sheeprock Range, Wah Wah Range, northeastern Utah or southeastern Idaho sections. Apparently, the structures are related to the difference in compaction between the limestones and shales.

That these "nodes" are the result of a break in the carapace is also shown by the fact that in many places the calcite has "penetrated" through the fracture and deposited on the dorsal side in the form of small mounds. These little mounds are often fused to form a small ridge covering the entire dorsal furrow. In many places where they are not fused, they also give the affect of nodes (pl. 17, fig. 3, fifth-seventh segments on the right side, and the posterior limb).

(5) During the course of thin section study of the calcite, a fine example of the axial articulation was discovered as shown in text-fig. 2.

TEXT-FIG. 2—Articulation of axial segments. Anterior to the left.

Plate 18, fig. 2, shows several excellent cross sections of both pleura and doublures of specimens preserved in a three-eighths inch limestone bed. Plate 18, fig. 3, illustrates a plan section of *P. interstrictus* (arrow). Plate 18, figs. 4–4c, show several cross sections of *P. interstrictus* in a calcite bed.

CARAPACE PRESERVATION

The carapace is, with minor exception, completely replaced by cryptocrystalline calcite. The majority of the weathered specimens generally appear a tannish gray, but may be dark-gray to shiny jet-black. The coloration differs markedly from horizon to horizon, the darker colors being associated with the darker calcareous shales (this sequence is in the lower one-fifth of the section and is a true shale) and to a lesser degree in the siltstones. In some cases, replacement by iron oxide and less often silicification was observed. Iron oxides commonly occupy and fill cavities of the carapace, particularly the cranidial and pygidial doublures and parts of the thorax. These individuals show a decided yellow-brown coloration and are most ideal for morphological studies.

CALCITE INCRUSTATIONS

As noted previously, the majority of the individuals are covered on their ventral surface by fibrous calcite. The thickness of the incrustation ranges from less than one to over seven millimeters, averaging 3–5 millimeters. The color varies greatly, but generally approximates the color of the calcite replacing the carapace.

The finely fibrous structure of the calcite is easily seen with the naked eye on most specimens. Inspection of fresh fractures with a hand lens sometimes reveals a finely granular to finely crystalline structure incorporated in the fibrous form.

The fibrous crystals of the incrustations are remarkably uniform in length. The resulting surface, formed by their terminations, is almost identical to the surface of the carapace to which they are affixed. Indeed, some of these surfaces are so perfect that almost all the ventral structures of the carapace are distinguishable (pl. 17, fig. 4). The surface formed by the ends of the crystals appears granular owing to the minor irregularities in length of the crystals and their habit of conical termination. Attempts were made to locate one of these calcite crystals with termination faces well enough preserved to study, but they all appear as blunt to conical points.

It is significant that in the vast majority of cases of *E. kingii*, the calcite grew on the ventral surface of the shell. In few instances is it found on the dorsal side, and it is even more uncommon on both sides. However, beds 5–10 mm. thick of the same fibrous calcite are commonly found containing a zone of randomly oriented *P. interstrictus* in the center (pl. 18, figs. 4–4c).

Assuming that the dead trilobite or its molted shell lay on the bottom in an upright position (almost all of the individuals found in place were upright) suggests a mode of origin for the incrustations. It is theorized that the principal soft parts of trilobites

were confined beneath the carapace. As the animal became buried its soft parts would decay giving off small amounts of ammonia. Because the carapace is convex upwards, most of the ammonia would be trapped beneath it and contact with bicarbonate bearing water would result in the precipitation of calcium carbonate. Hence, it is possible to explain the presence of the calcite on the ventral surface of the majority of the specimens. If, after compression by the compacting sediments had fractured the shell and some of the ammonia were able to escape through the fracture, a ready explanation for the occurrence of the dorsally occurring calcite mounds is apparent. Such an interpretation could also account for the fibrous calcite beds containing a zone of randomly oriented agnostids in the middle, decay of which would supply ammonia to both sides of the bed of organisms. Whether or not enough material remained on the ventral side of the molt test to supply sufficient ammonia to precipiate the calcium carbonate is debatable, but a point pertinent to the above hypothesis.

Authigenic pyrite is commonly included in the calcite as in the siltstones and few shales. That it post dates the calcite and the cone-in-cone is shown by the calcite structures abruptly terminated by the crystal faces of the pyrite (see pl. 18, fig. 6).

Walcott mentioned the existence of the cone-in-cone (1908*b*, p. 181) at the Wheeler Amphitheater and Tarr (1932, p. 725) made note of it. The numerous thin sections cut in the process of this study merely reaffirmed Walcott's original statement. Some of the best sections are figured in plate 18.

The writer feels that a complete discussion of the occurrence and origin of the calcite and the cone-in-cone is not appropriate to this paper. However, some of the observations made as they pertain to these fossils are listed:

(1) The formation of the cone-in-cone at this locality was directly controlled by the shape of the affixed carapace.

(2) The apex of every upright cone is opposite a dorsal depression in the carapace (e.g. the furrows). Any portion of the carapace which appears convex when viewed dorsally is the plane of attachment for the base of a cone (see pl. 18, esp. figs. 2–2d,5).

(3) The cones become progressively less prominent laterally, as the carapace becomes structurally less irregular (pl. 18, figs. 2c,5).

(4) Cone-in-cone was never found in a fibrous calcite bed without associated organic remains. Plate 18, fig. 8 is a thin section of a typical fibrous calcite bed 10 mm. thick lacking organic remains. This bed was found in one of the most prolific *E. kingii* horizons. Note the similarity of the cleavage structures between the calcite lacking cone-in-cone with that portion of pl. 18, fig. 4 (upper left corner) which did not develop cone-in-cone.

(5) Cone-in-cone is apparently not present in the associated limestones—with or without included organic remains (pl. 18, fig. 1).

(6) The combination of the uneven carapace and pressure was probably a factor in the development of the cone-in-cone. Solution appears not to have been a factor.

(7) Bedding apparently was not distorted by the growth of the calcite on the fossil. This would indicate that the sediments were still mobile enough to flow around the calcite.

(8) It is suggested that the chemistry of the various organisms was possibly a factor in the development of the calcite on their shells. Whether or not an individual is calcite-backed is dependent upon its kind. The following list presents the approximate percentage of each particular type of organism found with affixed calcite:

Elrathia kingii	95%
Bolaspidella housensis	95%
Peronopsis interstrictus	75%
Asaphiscus wheeleri	Rarely
Olenoides nevadensis	Rarely
Brachiopods	0

All the above are commonly found associated with *E. kingii* in the same beds.

(9) Precipitation of the calcite post dates or was contemporary to the crushing and fracturing of the individuals.

For the most recent discussions of cone-in-cone, the reader is referred to a discussion by Brown (1954, p. 372–376) on a fossil fish from the Green River (?) of Wyoming, and Pettijohn (1957, p. 209–210).

PALEOECOLOGY

Information available to the writer at the present time indicates that the extent of deposition of the Wheeler silts was a somewhat pear-shaped area, delimited by the Leppy Range on the northwest, the Promontory Range on the northeast, and the House Range to the south. As noted previously, all the known Wheeler equivalents surrounding this area are predominantly carbonates. This existence of a rather localized area of silt deposition in the carbonate facies of the Cordilleran miogeosyncline hints at some type of isolated environment —particularly in light of the silt and sand facies to the east of the carbonates. However, this study has failed to produce sufficient evidence to support such an interpretation.

The presence of Hyalospongea (in this instance, *Protospongia* sp.) is commonly considered indicative of deep water, along with the necessary water circulation for their support. However, considerable evidence gathered by the writer from numerous other localities in the Great Basin suggests that *Protospongia* is a shallow water form. It probably preferred an environment below wave base and not too far off-shore; hence, less than 600 feet deep. Little ecological significance can be attached to the single phyllocarid, as it easily could have been transported from a distant shore area. Likewise, the presence of the eocrinoids and the various brachiopods lend little information as to the probable environment.

The probability that the environment was one of relatively quiet water and below the zone of wave action is supported by several facts. (1) Although numerous fragmentary remains of the trilobites are found, there was a remarkably large percentage of the population preserved *in toto*. (2) The preponderance of the fauna is found right-side-up and generally parallel to the bedding. (3) Grain size of the total sediments is quite uniform, suggesting rather consistent but mild currents in the water. (4) Bedding is generally smooth and uniform, mostly defined by minor textural changes in the silts. (5) Although the brachiopods are mostly disarticulated, the single valves are well-preserved. (6) Major agitation most probably would have destroyed the delicate and well-preserved eocrinoids. (7) Juveniles and adults of all sizes are commonly found together in one bed, suggesting that the sorting action of the currents involved in the accumulation of the silts was not strong.

The color variegation of the sediments plus the sporadically occurring pyrite (usually in the darker zones) suggest a variation in the chemistry of the bottom waters and muds. In this connection, it is noteworthy that the darker zones generally contain a greater amount of the larger specimens of *E. kingii* along with the most brachiopods; while the lighter colored horizons have a smaller sized fauna, but are by far the more prolific zones.

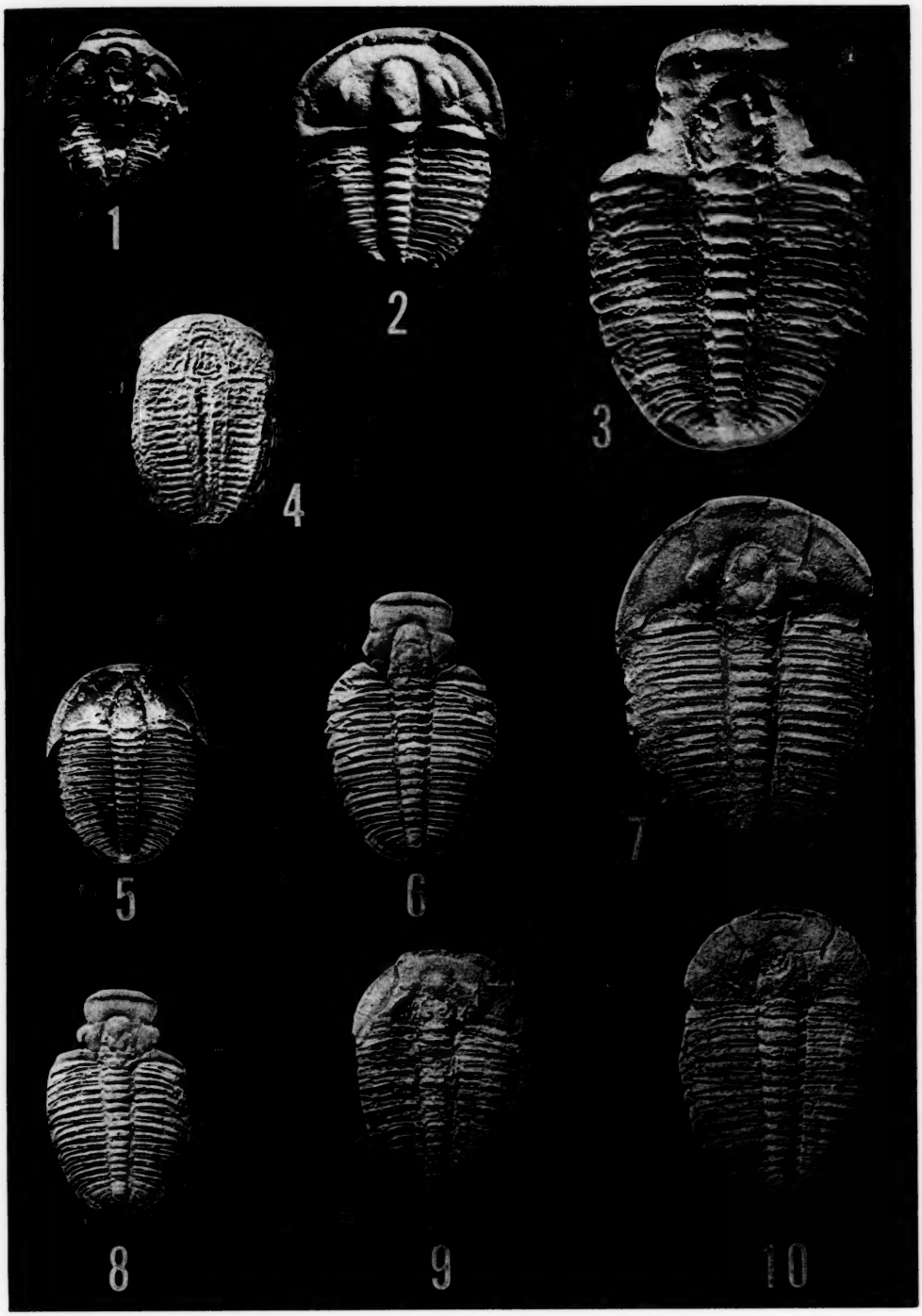
It is most probable that a calcareous, silty bottom was favored by *E. kingii* or they would be more common in the adjacent equivalent carbonates. In the Sheeprock Range, the Wheeler equivalent contains a few specimens of *E. kingii?* which are found almost exclusively in the silt partings of the limestones. It is puzzling, however, why the sections of the Leppy and Promontory Ranges, with their nearly identical lithologies, to date have yielded only one specimen even possibly referable to *E. kingii*. The whole population seems to be confined to the area in and around the Wheeler Amphitheater. Perhaps this species required an even more specialized environment that the calcareous, silty bottom suggested above.

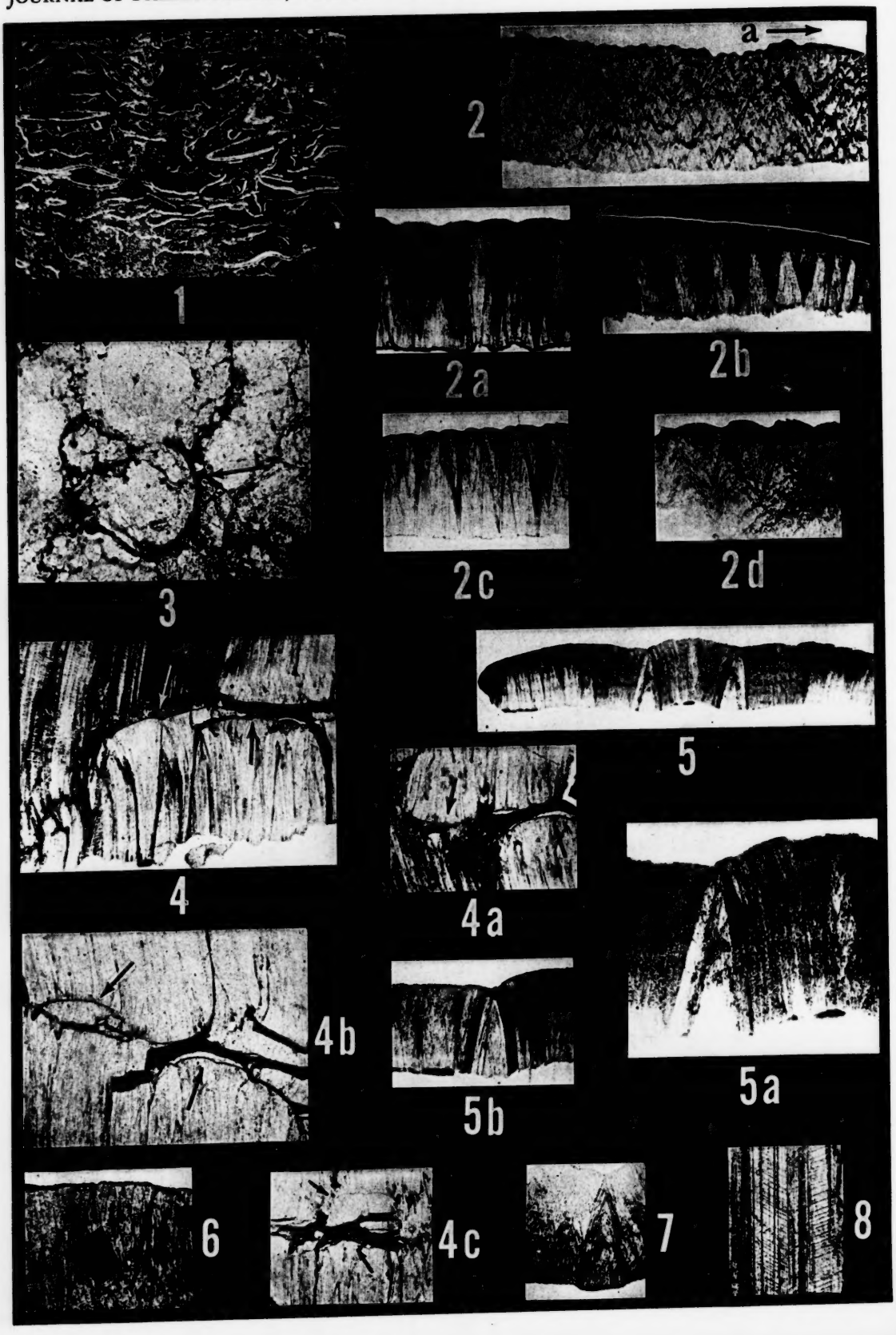
Considering the foregoing comments as a

EXPLANATION OF PLATE 17

FIGS. *1–3, 5–10—Elrathia kingii* (Meek), ontogenetic series. All topotypes. Fig. *5* is complete in every detail except for a small piece of the right genal spine. The fixed cheeks in Fig. *1* have been pushed to the rear. *1*, meraspis stage 10; *2*, meraspis stage 12; *3,5*, holaspids; *6–10*, adults; ×8,8,8,1,2,2,2,1,1,1, respectively.

4—Ventral view of a typical calcite incrustation showing how the calcite preserves the ventral surface of the carapace to which it has adhered.


1
2
3
4
5
6
7
8
9
10


a
1
2
2a
2b
2c
2d
3
4
4a
4b
4c
5
5a
5b
6
7
8

whole, a shallow semi-euxenic environment is suggested. However, not enough evidence is at hand to conclusively prove such a possibility.

The facts that the majority of the individuals are right-side-up, that there are so many complete specimens preserved, and that such a diversity in ages is represented probably precludes anything but a biocoenoses.

It is interesting that the occurrence of the agnostid *P. interstrictus* decidedly declines with the increased abundance of *E. kingii*. Whether there was a significant environmental change that was not favorable for the existence of the agnostid, or that *E. kingii* was predatory upon his smaller contemporary is unknown.

Natural decline and subsequent extinction of the *E. kingii* population within the Wheeler formation is postulated for the following reasons: (1) The overall population gradually increases from the bottom of the formation, reaches a maximum near the middle, and decreases towards the top to finally disappear at the end of Wheeler time. This suggests that as the environmental factors reached ideal conditions for existence and then slowly changed, so did the *E. kingii* population. Granted, there are numerous minor variations in concentrations within the formation, but minor environmental fluctuations could account for this. (2) Catastrophic extinction would be expected to have similarly affected the other faunal elements, which was not the case. *P. interstrictus* and the various brachiopods persisted in about the same numbers after the apparent disappearance of *E. kingii*. In addition, the overall abundance of the brachiopods seems little changed vertically. (3) The fact that thousands of articulated carapaces are found might imply catastrophic death, but further consideration shows that such need not be so. If the environment is deduced correctly—calm shallow water, weak current action, below wave base—and the individuals were not transported, then it is quite feasible that the molt and death tests could have been deposited, buried, and preserved articulated. In such conditions there would have been but minor mechanisms to effect disarticulation.

The writer considers the change in environment from one of a calcareous, muddy bottom and moderate water agitation to the

---

EXPLANATION OF PLATE 18

FIG. *1*—Thin section of a thin limestone bed, normal to bedding, showing the abundance of trilobite remains and lack of fibrous structure. Note the fine sections of axes, pleura, and doublures of *E. kingii*. (arrows). ×8.

2—Sagittal section showing numerous "layers" of cone-in-cone. Occipital ring beneath the rear of the arrow, which points anterior. ×2.

2a,*2d*—Sagittal sections showing some extra well-developed cone-in-cone. Note how the cones are controlled by the structure of the carapace. ×4, 4 respectively.

2b—Sagittal section of specimen still adhering to the siltstone on the dorsal side. Apex of each cone opposite a furrow or dorsal depression. ×2.

2c—Exsagittal section. Note decrease in lateral intensity of the cones. ×5.

3—Thin section of fibrous calcite bed, parallel to bedding, containing remains of the agnostid *Peronopsis interstrictus*. Note the section of the agnostid (arrow). Section normal to the calcite fibers. ×8.

4–4c—Thin sections of a fibrous bed of calicte, normal to bedding. Zone of *P. interstrictus* in the middle (arrows). This is the only common occurrence of fibrous calcite on both sides of the carapace in the Wheeler formation. Note how the cone-in-cone is controlled by the irregularities of the carapace. ×6,3,6,3, respectively.

5–5b,*7*—Cross sections of several specimens of *E. kingii* showing the pronounced cone beneath the dorsal furrow. *5*a is an enlarged view of the left dorsal furrow of *5*. Note the decrease in lateral intensity of the cones in 5. Note the distinct difference in the cone structure between *5*b and *7*—as yet unaccounted for. ×4,8,5,5, respectively.

6—Exsaggital section showing included pyrite cubes. Note how the cone-in-cone is terminated by the pyrite. ×3.

8—Thin section of a common layer of fibrous calcite normal to the bedding without included organic material. Note similarities to the upper left corner of 4 which shows some cleavage structure. ×12.

highly calcareous and greatly reduced silt environment of the overlying Marjum a credible cause for the decline of *E. kingii* at the end of Wheeler time.

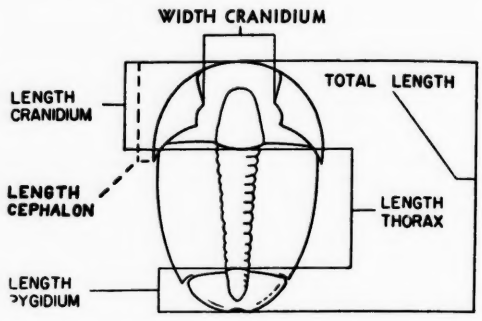
QUANTITATIVE STUDY

The ensuing statistical study of *E. kingii* is based on a collection of 339 complete individuals, ranging in size from 3.1 mm. to 49.7 mm. It will be noted, however, that some of the analyses are based on less than the 339 specimens because of imperfect preservation. With the exception of the length of the cephalon, about 330 individuals were used for the various sets of data.

It is the writer's opinion that quantitative studies merely supplement qualitative ones, and that the role of the former is to further attest to or refute an hypothesis based on qualitative observations.

In any quantiative study, the initial problem that confronts the worker is if his collection is a valid representation of the population being sampled. In other words, was the collecting biased—did the collector save only the large individuals or did he collect every size available; were only specimens with certain features retained; or, were only the well-preserved ones kept? In this regard the writer must confess the sample is somewhat biased, in that only complete specimens were used and even some of the complete ones were discarded because of preservation. Numerous molts were included, however, in spite of the collecting techniques, so the collection was not totally biased in this respect. It is felt that the bias does not adversely affect the particular objectives of this study.

The second problem is: whether or not the sample truly represents the total population. That is, due to the usual vagaries of preservation, were only certain sizes, shapes, or those in particular environments, etc. fossilized? In all probability, the sample at hand represents the living population and part of the molt tests *above* the 3.1 mm. size. The population below the 3.1 mm. size is *poorly* represented in the study due to inability to collect any this small well enough preserved to study. Several curves were thus affected below the 3.1 mm. size; but, again, the objectives of the study are not appreciably affected.



TEXT-FIG. 3—Diagram indicating method of making the various measurements.

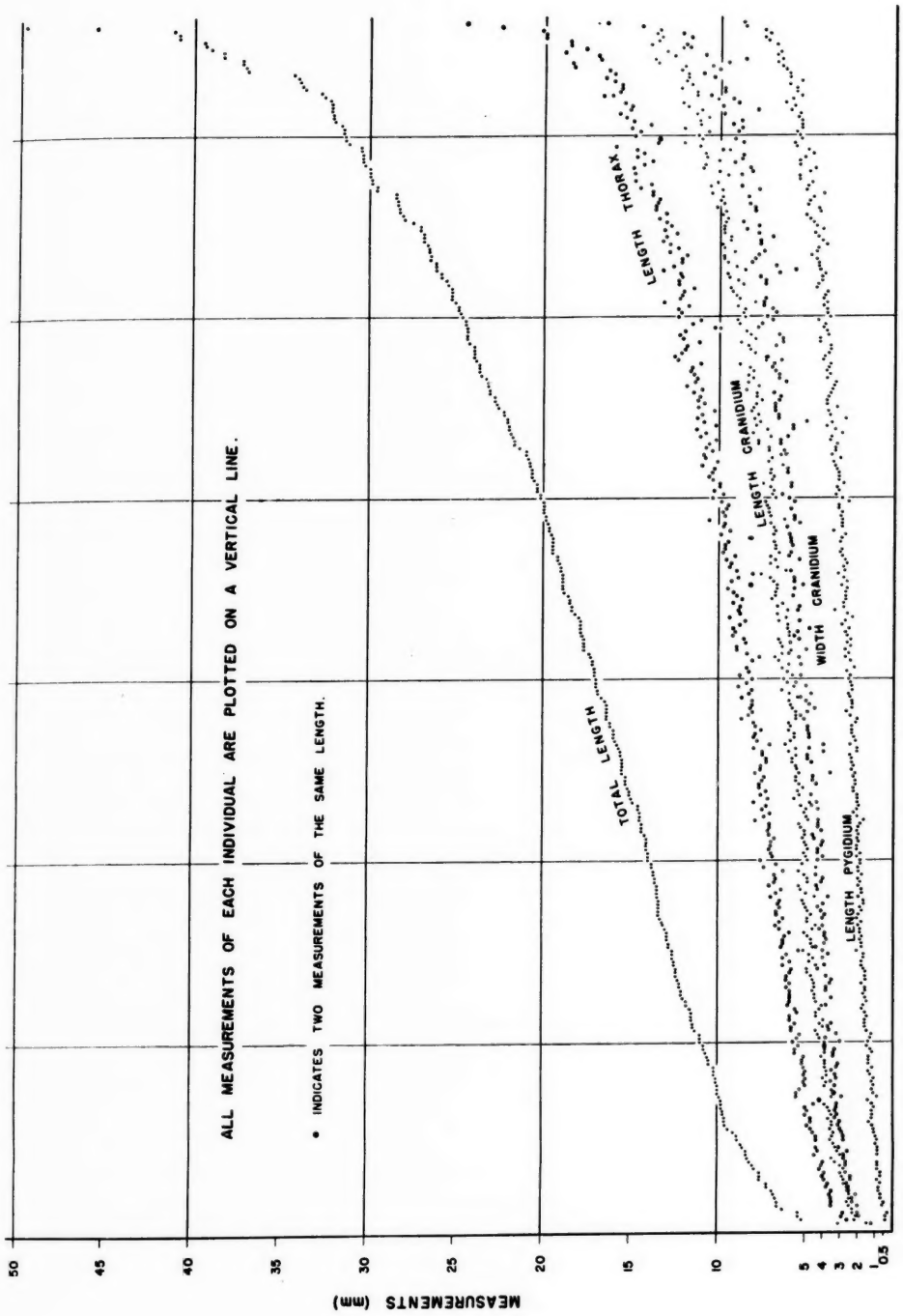
Measurements were made with a scaled caliper to 0.1 mm. as show in text-fig. 3.

The following is a list of abbreviations representing the various measurements as used in the text. The terminology proposed by Shaw (1957, p. 193–207) for measuring trilobites is indicated in parentheses at the right.

CE = Length cephalon	
CR = Length cranidium	(A_1)
CW = Width cranidium	(J_4)
TH = Length thorax	(Q)
PY = Length pygidium	(Z_1)
TL = Total length	(P)

Cumulative distribution.—The cumulative distribution (text-fig. 4) is important in the case of *E. kingii*. The total length of all specimens was cumulated from the smallest to largest and plotted on the graph in order of increasing size. The other measurements (CR, CW, TH, and PY) were then plotted in a vertical line for each individual. As will be shown later, the abscissa may represent time or relative age.

Scrutiny of the graph immediately leads to several plausible inferences. (1) It is obvious by inspection that none of the curves are absolutely parallel. As the individuals increase in size the curves become farther apart. Whether or not growth was isometric is not apparent from this graph, however, is suggested. (2) Growth was not discontinued at the adult stage. Had this been the case, the curve would have leveled off at some point and been nearly horizontal. This substantiates Moore's (1952, p. 486) comment ". . . adult trilobites may continue to become larger at each time of molting until the individual dies." The sudden steepening of



TEXT-FIG. 4—Cumulative distribution of various parts of *E. kingii*. Note the divergent trends of the various parts.

the curve does not indicate a growth rate increase, but merely that individuals of this size were uncommon. (3) The steepening of the lower end of the curve might be construed to mean accelerated growth in the younger individuals; however, it was pointed our earlier that the sample is biased below 3.1 mm. Therefore, this portion of the curve is probably unnatural and should have a flatter slope. (4) Since growth is continuous until death, it is reasonable to assume that the total length (within limits) represents the relative age of an individual. It is recognized that individual variation modifies this assumption, but length is a usable tool as a reliably close estimate of the age of individuals of the same species. (5) Early in the study, it was theorized that such a cumulation might reveal molt stages by one of the curves appearing in a step-like fashion. However, it is apparent that the curves are quite continuous with no trace of a molt stage. Whether or not this was the result of the sample bias or individual variation is not known for certain. I rather think there were enough specimens in the sample to show molt stages if they were to be reflected by the graph.

Rectilinear relationships.—It will be noted that most of the relationships were plotted on rectangular coordinates, rather than the usual logarithmic scales used by many workers. After trying both the writer believes the rectangular plots serve the purposes of this study best.

The five relationships shown in text-figs. 5 and 6 can all be considered together owing to certain similarities common to all. Inspection readily reveals that all five sets of data are best fitted to rectilinear regressions.

One striking similarity noted in all five graphs is that as the size of one variable increases, the variation of the other increases. Evitt (1953, p. 47) noted this in his studies of the Ordovician trilobite *Ceraurus*. He said, "In the more advanced degrees there is greater variation in the magnitude of the dimensions considered than occurs in the earlier degrees. This is probably the result of a more prolonged exposure to environmental factors on the part of older individuals." However, referring to the relationship CR, TL (text-fig. 5), it will be noted that the coefficient of variance (proportional variance) remains about 41.8%, but the absolute variation increases to the right. If the coefficient of variance is to remain the same for the growth series, the absolute variation must increase with size; therefore, the relationships for *E. kingii* are considered quite normal.

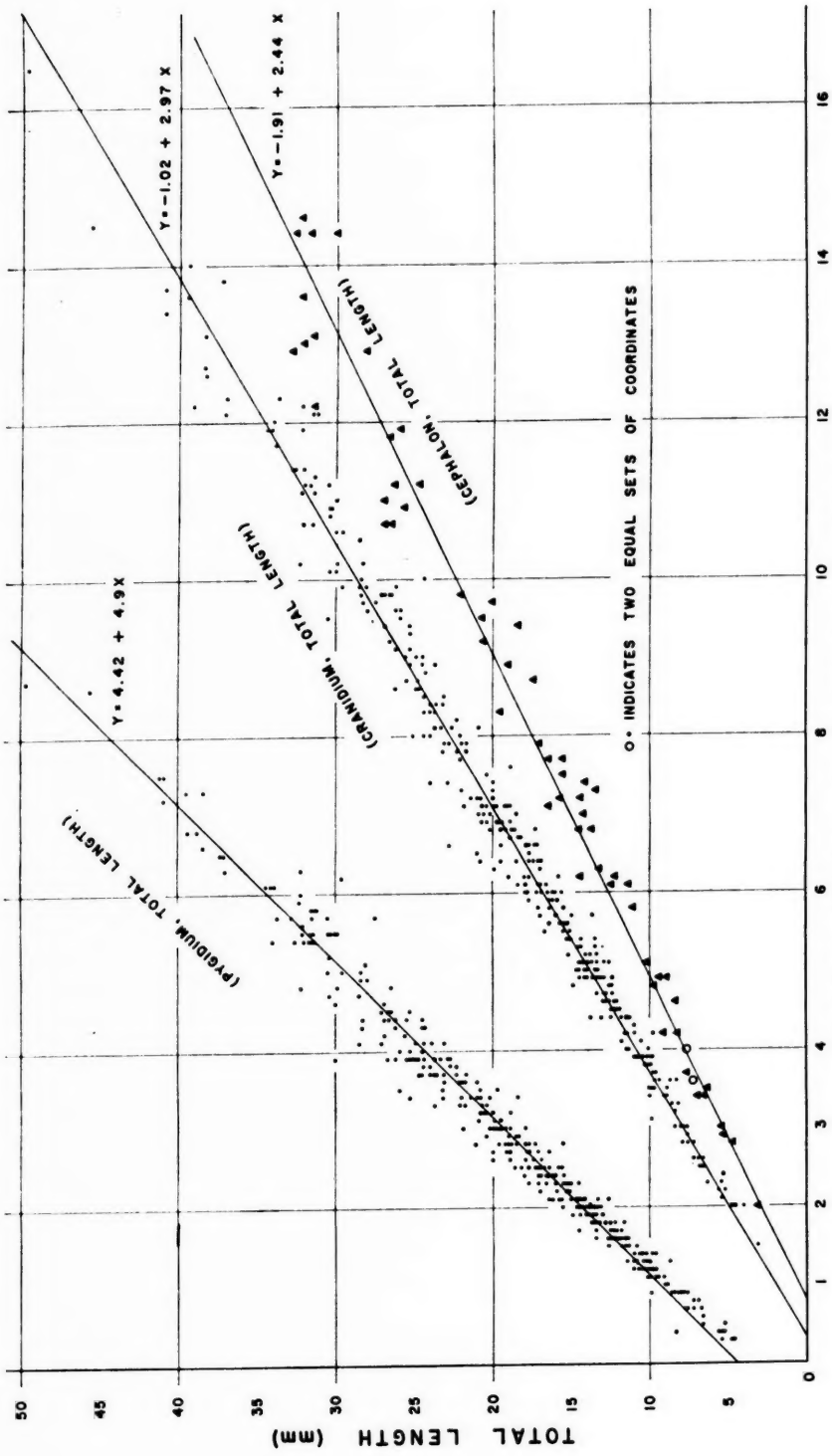
Tests of t were computed for the five curves; they showed the relationships to be highly significant statistically (table 2).

Ratios.—After the linear relationships discussed above were plotted, selected ratios were computed in order to verify changes of growth rates and to find out just where they began their relative changes. For example: in text-fig. 6, the relation CR, PY is shown; it is a straight line and no change in growth rates can be detected; so the coordinates were converted to percentages. Each percentage was then plotted against a corresponding total length. The resulting curve (text-fig. 7) is concave showing that as the total length increased the length of the cranidium decreased with respect to the length of the pygidium. Note that the regression appears linear from 50 to about 15 mm., at this point it turns abruptly upward in a curvilinear fashion.

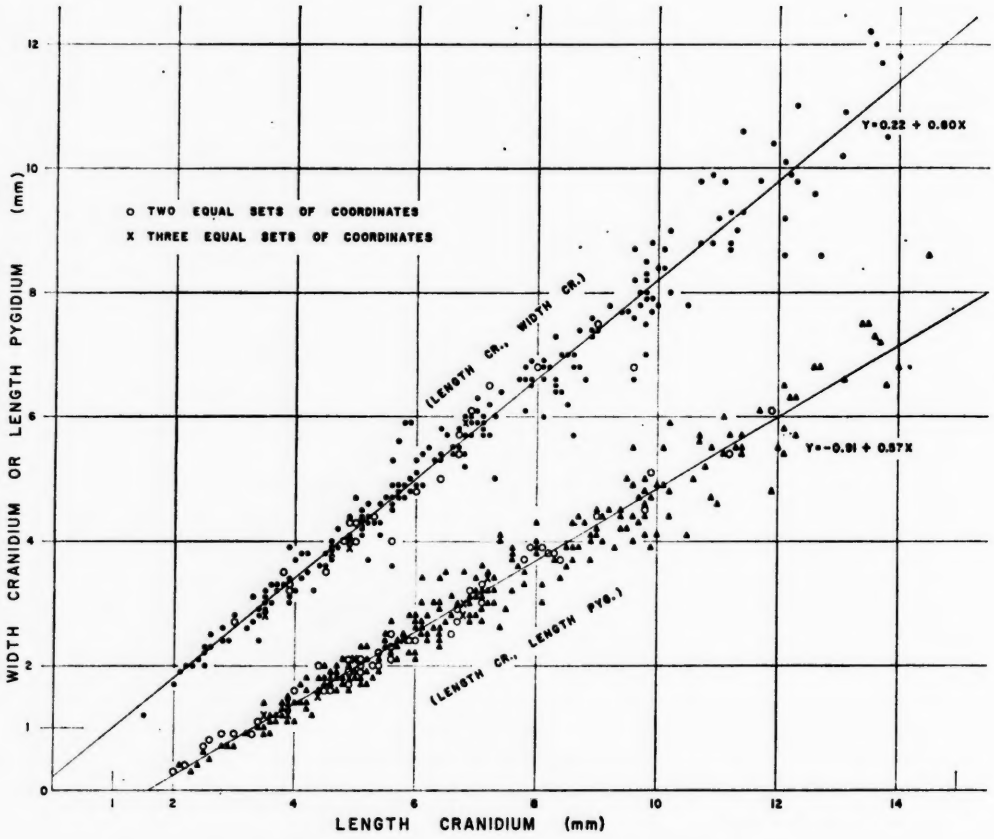
It can be readily demonstrated mathematically that any linear regression converted to ratios, if it does *not* pass through the origin, *will be a curved line;* further, it will be parabolic. Only a portion, however, of the total curve may be represented by the organism (e.g. CW/CR, TL, text-fig. 7).

Ratio of CW/CR.—This set of data is best fit by a linear regression (text-fig. 7). As noted previously, however, this is actually a part of the limb of a parabola, but the known portion represented by *E. kingii* is so nearly straight that it is impractical to consider it curved. The test of t indicates a significant relationship for the data. The coefficient of determination ($r^2 = 0.0576$) indicates that only 5.76 percent of the variation in the ratio CW/CR as measured by the sums of squares is explained by the linear regression of CW/CR on the total length.

Ratio of CR/PY.—Text-fig. 7 shows the decrease in length of the cranidium relative to the pygidium as total length increases. At about 16 millimeters the regression approaches linearity. This graph indicates the differential growth rates of the cranidium and



TEXT-FIG. 5—Scatter diagram of the relationships PY, TL; CR, TL; CE, TL. Note increasing absolute variation with length.


WIDTH CRANIDIUM OR LENGTH PYGIDIUM (mm)
LENGTH CRANIDIUM (mm)
o TWO EQUAL SETS OF COORDINATES
x THREE EQUAL SETS OF COORDINATES
Y=0.22 + 0.80X
Y=-0.91 + 0.57X
(LENGTH CR., WIDTH CR.)
(LENGTH CR., LENGTH PYG.)

TEXT-FIG. 6—Scatter diagram of the relationships CR, CW; CR, PY.

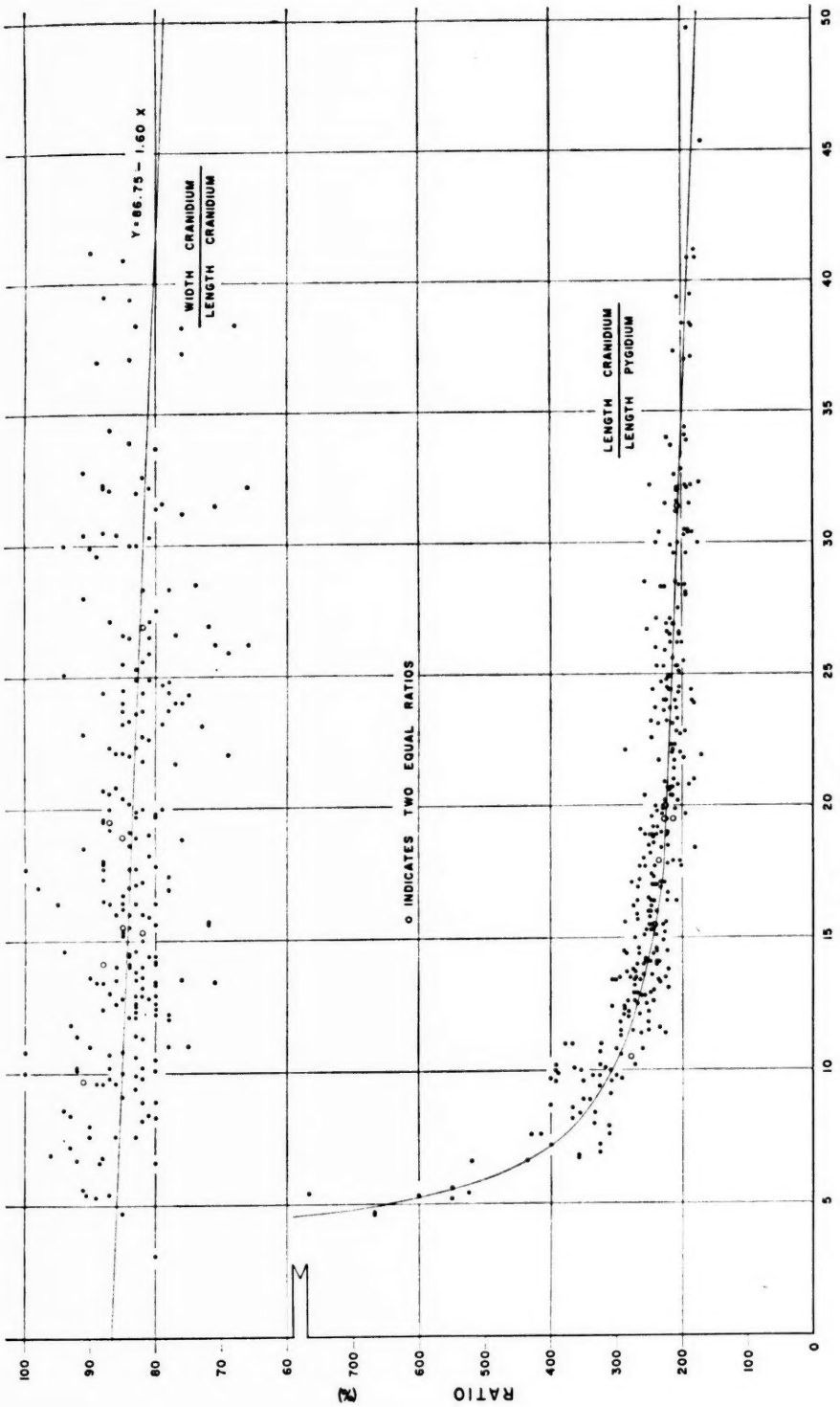
pygidium with respect to each other.

Ratio of TH/TL.—Although the curve shown in text-fig. 8 is a part of a highly convex parabola, it may be treated as though it were linear since the curvature is no minor. Test of t indicates a significant relationship of the data. The coefficient of determination ($r^2 = 0.1403$) indicates that 14.03 percent of the variation of TH/TL as measured by the sums of squares is explained by the regression of TH/TL on the total length. Consequently, approximately 85.97 percent of the variation is due to chance alone.

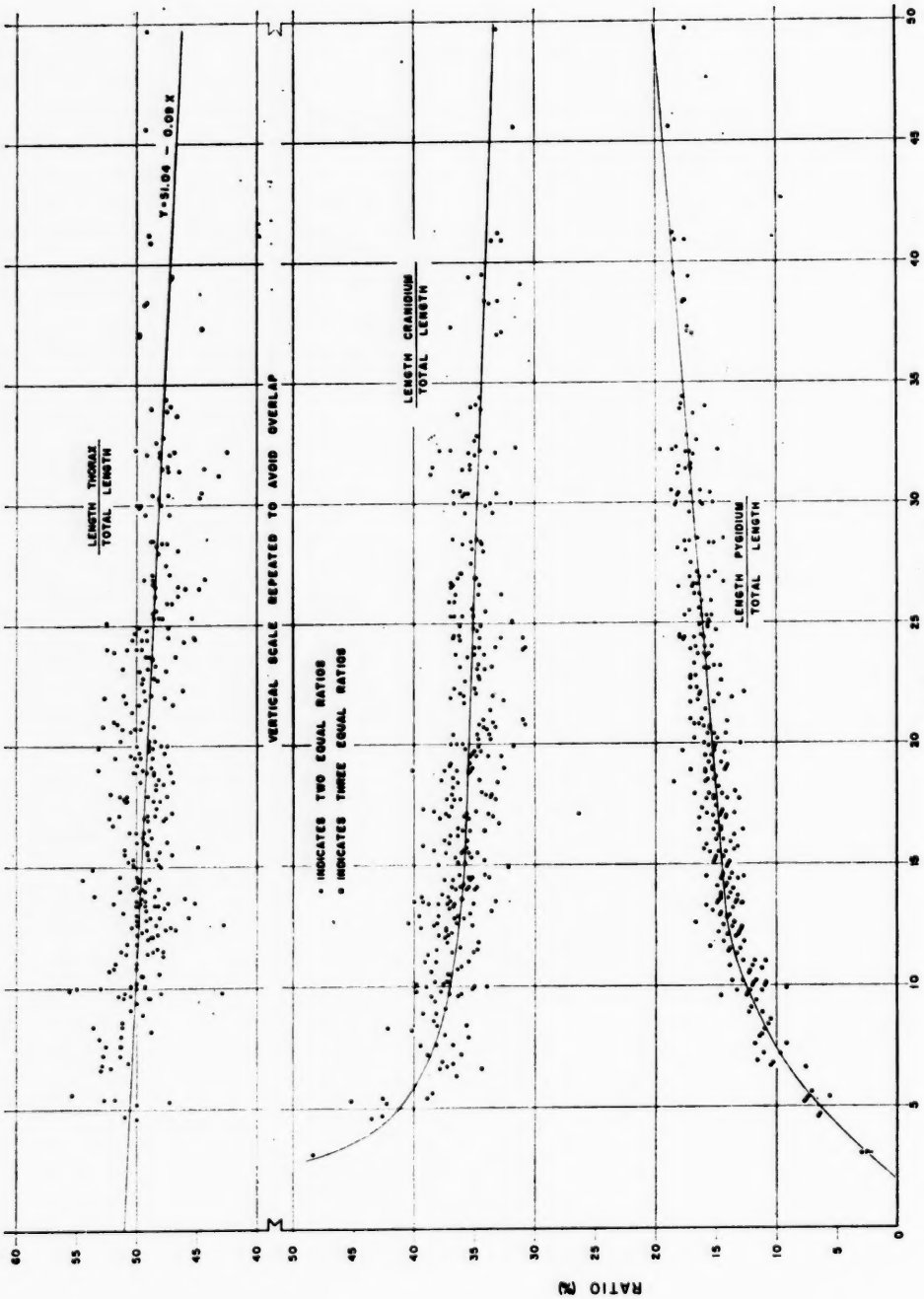
Ratio of CR/TL.—As indicated by the curve in text-fig. 8, the length of the cranidium is inversely proportional to the total length. Although little data appears on the graph from 0–5 mm., the writer is confident of the trend of the curve. Several tiny specimens (2–4 mm. long) are at hand, not well enough preserved for accurate measurement, which have cranidia at least 45–70 percent of their total lengths. They were not plotted on the graph, as it was desirable to present only the most accurate data possible. At about sixteen millimeters, the regression becomes almost linear to the right. This indicates a change to an almost constant rate of change of the growth ratio.

The fact that the ratio is always decreasing came as a surprise, since it was thought that the ratio would become constant when the individual reached the adult stage.

Ratio of PY/TL.—The relative rate of growth of the pygidium is directly proportional to the total length (text-fig. 8). Evitt (1953, p. 46) noted the same in *Ceraurus*. The rates of change seem to become relatively constant at about 15 mm. as in the foregoing cases. From this point the curve



TEXT-FIG. 7—Scatter diagram showing the change in the ratios CW/CR and CR/PY with an increase in the total length (or age).


LENGTH THORAX / TOTAL LENGTH
Y=31.04 − 0.09 X
VERTICAL SCALE REPEATED TO AVOID OVERLAP
LENGTH CRANIUM / TOTAL LENGTH
• INDICATES TWO EQUAL RATIOS
o INDICATES THREE EQUAL RATIOS
LENGTH PYGIDIUM / TOTAL LENGTH
RATIO %
TOTAL LENGTH (mm)

TEXT-FIG. 8—Scatter diagram showing the change in the ratios TH/TL; CR/TL; PY/TL with an increase in the total length (or age). Note the apparent rectilinearity of the two lower plots at a point of about fifteen mm.

may be considered linear to the right or with an increase in age.

The steady increase of the pygidium with size is adjusted for by the combined decrease of the thorax and cranidium. Just why such a relationship is difficult to interpret; however, it seems that the consistency of the changes warrants a genetic, physiological, or evolutionary explanation. It is interesting to note that the change in relative proportions of the pygidium and thorax seem to parallel trilobite evolution in general.

Although the foregoing method of plotting ratios is somewhat unique in trilobite study, the writer feels that the method can become extremely useful in defining growth rate changes and even in descriptions. It may become necessary, as more relationships are plotted for other trilobites, to define the regressions by Huxley's formula $y = bX^k$, which was not considered necessary for purposes of this study.

Use of ratios.—Shaw (1956, p. 1212–1214) has ably discussed the various aspects of the use of simple ratios as a descriptive and taxonomic tool; he concluded ". . . the use of ratios cannot be recommended."

Several conclusions concerning ratios are listed as a result of this study: (1) Description of trilobites by merely indicating a simple ratio (e.g. $\frac{1}{3}\pm$) or the mean ratio of a certain proportion (e.g., length cranidium to total length) is not adequate. Such usage presumes a linear regression for the particular ratio; which was shown earlier not usually to be true. Each ratio for each species must be considered singularly and for the life of the animal. (2) Shaw (1956, p. 1213) pointed out the possibility of demonstrating quantitative differences in opposite ends of a growth series. This was re-emphasized by construction of the various ratio curves—particularly PY/TL (text-fig. 8). (3) Ratios *can be* a useful taxonomic tool if the worker is cognizant of their inherent variation, and *accounts for this in this usage.* To state that the ratio of the length of the cranidium to the total length varies from $\frac{1}{3}$ to $\frac{2}{3}$ is perhaps adequate for the adult *E. kingii* (after considering the growth series), but completely erroneous for all stages of growth. Text-fig. 8 indicates this ratio varies from 30–50 percent in just the holaspis and adult. To further illustrate the point, consider Palmer's (1954, p. 78) recent interpretation of the genus *Elrathia* where he states "Width of fixed cheeks one-half or more width of glabella." According to this strict definition, the specimen in pl. 17, fig. 10 is not an *Elrathia* because the fixed cheeks are *less* than one-half the width of the glabella (the same is to be said for at least 30 others not figured). Obviously, this is not the case qualitatively which further points out the weakness of such usage of ratios. In order to be useful in this manner, regressions must be computed and fiducial limits set, which is most difficult with parabolic curves given by ratios. (4) Ratios plotted in the manner presented herein can be useful in graphically portraying and deducing relative rates of change of growth and *estimating probable variance limits* of ratios.

Various data calculated for the study are presented in Tables 1–3 for the convenience of those who desire to compare *E. kingii* with other trilobites. Although the data presented in table 1 are not useful for quantiative comparison, they are included for those who may want the information. The following abbreviations as used are defined:

s.d. = Standard deviation.
N = Number of specimens in sample.
S^2_{yx} = Variance from regression.
S_b = Standard error of the regression coefficient.
t = t value
P = Probability
r^2 = Coefficient of determination
r = Coefficient of correlation

TABLE 1—TABLE OF MEANS, STANDARD DEVIATIONS, AND SAMPLE SIZES

Statistic	CE	TL	CR	CW	TH	PY
Mean	7.978 mm.	19.3 mm.	6.799 mm.	5.598 mm.	9.525 mm.	3.007 mm.
s.d.	3.65	8.01	2.84			1.60
N	68	341	339	253	329	333

TABLE 2—VARIOUS DATA FOR THE SEVERAL RELATIONSHIPS OF PARTS OF *E. kingii*

	PY, TL	CR, TL	CE, TL	CR, CW	CR, PY	TL, $\frac{CW}{CR}$	TL, $\frac{TH}{TL}$
Regression Formula $Y=a+bX$	TL = 4.42 +4.97 PY	TL = −1.02 +2.97 CR	TL = 1.91 +2.44 CE	CW = .22 +.80 CR	PY = −.91 −.57 CR	Y = 86.84 −.16 TL	Y = 51.04 −0.09 TL
S_{yx}^2	0.4084	1.4857	6.40813	0.1658	0.08797	29.31485	3.69269
S_{yx}	0.2021	1.219	2.5313	0.4072	0.2966	5.41438	1.9216
S_b	0.006848	0.02439	0.08162	0.009245	0.0001171	0.04195	0.012837
t	725.671	121.71	29.8838	86.4018	4885.805	3.90934	7.3074
P	<.01	<.01	<.01	<.01	<.01	<.01	<.01
95% confidence limits of "b"	L_1 = 4.9557 L_2 = 4.9826	L_1 = 2.950 L_2 = 3.0149	L_1 = 2.2792 L_2 = 2.5991	L_1 = 0.78065 L_2 = 0.81689	L_1 = 0.5719 L_2 = 0.5723	L_1 = 0.2462 L_2 = 0.08178	L_1 = .068647 L_2 = .11897
r^2	0.9938	0.9788	0.9275	0.9675	0.9664	0.057612	0.140369
r	0.9967	0.9894	0.9631	0.9836	0.983	0.240025	0.37466

BIBLIOGRAPHY

BRIGHT, ROBERT C., 1957, New look at *Elrathia kingii* (Trilobita): Geol. Soc. America Bull. (abstract), v. 68, no. 12, pt. 2, p. 1859–1860.

BROOKS, H. K., & CASTER, K. E., 1956, *Pseudoarctolepsis sharpi*, (Phyllocarida), from the Wheeler shale (Middle Cambrian) of Utah: Jour. Paleontology, v. 30, no. 1, p. 9.

BROWN, ROLAND W., 1954, How does cone-in-cone material become emplaced?: Am. Jour. Sci., v. 252, no. 6, p. 372–376.

BURMA, B. H., 1948, Studies in quantitative paleontology: I. Some aspects of the theory and practice of quantitative paleontology: Jour. Paleontology, v. 22, p. 725–761.

——, 1953, Studies in quantitative paleontology, III. An application of sequential analysis to the comparison of growth stages and growth series: Jour. Geology, v. 61, no. 6, p. 533–543.

DEISS, CHARLES, 1938, Cambrian formations and sections in part of the Cordilleran trough: Geol. Soc. America Bull., v. 49, p. 1067–1068.

EVITT, W. R., 1953, Observations on the trilobite *Ceraurus:* Jour. Paleontology, v. 27, no. 1, pp. 33–48.

HOWELL, B. F., et al., 1947, Terminology for describing Cambrian trilobites: Jour. Paleontology, v. 21, no. 1, p. 72–76.

IMBRIE, JOHN, 1956, Biometrical methods in the study of invertebrate fossils: Bull. Am. Mus. Nat. History, v. 108: Art. 2, p. 217–252.

MEEK, F. B., 1870, Descriptions of fossils collected by U. S. Geol. Survey: Acad. Nat. Sci. Phila. Proc. for 1870, p. 56–64.

MOORE, R. C., 1952, *in* MOORE, LALICKER, & FISCHER, Invertebrate fossils: McGraw-Hill Book Co., Inc., p. 463–520.

PALMER, A. R., 1954, An appraisal of the Great Basin Middle Cambrian trilobites described before 1900: U. S. Geol. Survey Prof. Paper 264-D, 83 p.

PETTIJOHN, F. J., 1957, Sedimentary Rocks: Harper Bros., N. Y., p. 209–210.

RASETTI, FRANCO, 1941, Middle Cambrian stratigraphy and faunas of the Canadian Rocky Mountains: Smithsonian Misc. Coll., v. 116, no. 5.

RICHARDSON, W. A., 1923, The veins of "beef": Quart. Jour. Geol. Soc. of London, v. 79, p. 89–95.

SHAW, ALAN B., 1956, Quantitative trilobite studies I. The statistical description of trilobites: Jour. Paleontology, v. 30, no. 5, p. 1209–1224.

——, 1957, Quantitative trilobite studies II. Measurement of the dorsal shell of non-agnostidean trilobites: Jour. Paleontology, v. 31, no. 1, p. 193–207.

STØRMER, L., 1939, Studies on trilobite morphology, Part I, The thoracic appendages and their phylogenetic significance: Norsk Geol. Tidskr., v. 21, p. 49–164.

TARR, W. A., 1932, *in* TWENHOFEL, Treatise on sedimentation, Second Edition: Williams and Wilkins Co., p. 717–733.

WALCOTT, C. D., 1908*a*, Nomenclature of some Cambrian Cordilleran formations: Smithsonian Misc. Coll., v. 53, No. 1, p. 9–12.

——, 1908*b*, Cambrian sections of the Cordilleran area: Smithsonian Misc. Coll., v. 53, no. 5, p. 179–182.

WHEELER, H. E., 1948, Late Pre-Cambrian—Cambrian stratigraphic cross section through southern Nevada: Univ. Nev. Bull., v. XLII, no. 3, 63 p.

——, & STEELE, GRANT, 1951, Cambrian sequence of the House Range, Utah, *in* Intermountain Assoc. Pet. Geol. Guidebook to the Geology of Utah: no. 6, p. 29–37.

MANUSCRIPT RECEIVED JUNE 11, 1958.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 99–102, PL. 19, JANUARY 1959

BAYHAIUM MERRIAMORUM, A NEW PERMIAN TABULATE CORAL FROM CALIFORNIA

R. L. LANGENHEIM, JR. AND V. A. MCCUTCHEON
University of California, Berkeley

ABSTRACT—*Bayhaium merriamorum, n. gen., n. sp.*, is described from the lower and middle McCloud limestone, Wolfcampian of Shasta County, California. *Bayhaium* is referred to the Syringoporinae although it is also morphologically related to the Syringophyllinae and Pachyporinae.

INTRODUCTION

With the exception of Thompson, Wheeler & Hazzard's description (1946) of the fusulinids, little has been published concerning the fauna of the McCloud limestone since Meek's pioneer description (1864) of a few corals and other invertebrates. Other workers, however, have compiled an extensive list of fossil invertebrates and generally have concluded that the Northern California Permian faunas are of Asiatic rather than Middle North American affinities. Thus, collection of a large tabulate coral with distally thickened corallite walls, apparently a *Thamnopora*, was of interest because Permian *Thamnopora* spp. are known only from Australia, Timor, Japan and India. Detailed study, however, quickly showed that the McCloud limestone coral is not a *Thamnopora* but is a new syringoporoid with some characters similar to those of early Paleozoic syringophyllids. We are therefore recording this interesting new tabulate coral as a contribution to knowledge of a little-known Permian fauna.

Thanks are due Robert Kaar, Alan Coogan, Dale Duley, Robert Loney, Stephen Shank and Paul Wesendunk who helped in collecting fossils. This paper is a contribution from the Museum of Paleontology of the University of California at Berkeley.

SYSTEMATIC DESCRIPTIONS

Class ANTHOZOA
Order TABULATA
Family AULOPORIDAE Milne-Edwards & Haime, 1851
Subfamily SYRINGOPORINAE Nicholson, 1879
Genus BAYHAIUM, n. gen.

Diagnosis.—Bayhaium is characterized as a ceroid syringoporoid coral with well-defined mature and immature regions. The mature portion of the corallite is thick-walled, septate, and normal to the surface of the corallum. The immature portion of the corallite is thin-walled, nonseptate and inclined with respect to the axis and surface of the corallum.

Description.—Corallum massive, ramose, dominantly ceroid. Corallites prismatic in ceroid portion of corallum, cylindrical in restricted phaceloid areas of outermost mature portion. Mature portion of corallite sharply differentiated from immature portion, immature corallites thin-walled and diverging at low angles from axis of corallum, mature corallites essentially perpendicular to corallum surface with walls thickened by sclerenchyme, septa in mature portion of corallite only. Walls separate, composed of a single layer of prismatic crystals normal to wall, greatly thickened by septal sclerenchyme in mature region. Tabulae complete, strongly infundibular in immature region, infundibular to concave in mature region. Septa represented by 18 to 24 sclerenchymal ridges, septal ridges coalesce forming alternating layers of thick and thin-wall structure in mature portion of corallum. Irregularly spaced, tunnel-like connections between corallites. No axial structure or axial tube.

Type species.—Bayhaium merriamorum n. sp.

Name.—The settlement of Bayha and Bayha Creek are located in the vicinity of the type locality of the genotype, *Bayhaium merriamorum, n. sp.*

Remarks.—The distally thickened walls of *Bayhaium* and the gross morphology of the corallum suggest a link with the Pachyporinae, especially *Thamnopora*. *Thamnopora* spp., however, have fewer septa. Also

the strongly infundibular tabulae and syringoporoid connecting tubules of *Bayhaium* contrast sharply with the horizontal tabulae and numerous mural pores of *Thamnopora* and *Striatopora* (Etheridge, 1891, p. 25–28, pls. I, VI, 1914, p. 13–14, pls. I,II,VIII; Gerth, 1921, p. 105–109,112, pls. 148,150; Hehenwarter, 1951, p. 62–65, pl. IV; Hill, 1937, p. 56–58, pl. I, 1942, p. 65–68, pls. I,II; Hill & Stumm, 1957, p. 464, figs. 351,352; Lecompte, 1939, p. 102–135, pl. XV–XVIII, 1952, p. 511–512, figs. 23–25; Minato, 1955, p. 184–185, pls. 40,41; Moore & Jeffords, 1945, p. 175–181, pl. 14, text-figs. 185–189, 194–201; Rothpletz, 1892, p. 67, pls. XI,XII). *Acaciapora* (Moore & Jeffords, 1945, p. 181–185, pl. 14, text-figs 190–193, 202–203) has incomplete tabulae and *Heterocoenites* (Gerth, 1921, p. 109–111, pls. 149,150) has proximally thickened walls. Thus all of the Late Paleozoic genera of Pachyporinae are distinct from *Bayhaium*, although *Bayhaium* has thickened walls of the sort characterizing the Pachyporinae. The older pachyporoid genera are readily distinguished from *Bayhaium*.

Bayhaium resembles *Lyopora* (Syringophyllinae) in the number of septa and in the manner in which septa and sclerenchyme appear in the mature portion of the corallum (Okulitch, 1950, p. 264–265, pl. 16). It is sharply distinguished, however, by its strongly infundibular tabulae.

Bayhaium is distinguished from all genera of Syringoporinae except *Roemeria* by its predominantly ceroid habit. *Syringopora geniculata* Phillips, *S. reticulata* Goldfuss and *S. caespitosa* Goldfuss have closely spaced corallites, but they are definitely phaceloid (Hinde, 1890, p. 198–199, pl. VIII; Lecompte, 1936, p. 90–93, pl. XIII; Milne-Edwards & Haime, 1854, p. 161–164, pl. XLVI). Furthermore the corallites of *Syringopora* do not have sharply differentiated mature and immature regions and their walls are not thickened. Several species of *Hayasakaia* have closely spaced corallites, but the corallum is phaceloid, the corallites are not differentiated, the walls are not thickened, and, in addition, the tabulae are horizontal. *Roemeria* most closely resembles *Bayhaium* of all syringoporoid genera. The genotype, *R. infundibulifera* (Goldfuss), is, however, thick-walled throughout and lacks prominent septa (Lecompte, 1936, p. 68–80, pl. XII). *R. kunthiana* Lindstrom has numerous mural pores and the tabulae are not strongly infundibuliform (Tripp, 1933, p. 130–131, pl. XVI, test-figs. 48,49). *R. minor* Schlüter has thick walls throughout but closely resembles *Bayhaium* in other respects (Nicholson, 1899, p. 433–436, figs. 1–3). Lecompte (1936, p. 74) also strongly emphasizes the two-layered wall structure of *R. infundibulifera* as a defining character of *Roemeria*. *R. bohemica* Barrande has dissepiments and has been made the genotype of *Roemeripora* (Kraicz, 1934). Thus none of the species of *Roemeria* (including *R. bohemica*) appear congeneric with *Bayhaium*. *Roemeripora wimani* Heritsch (1939, p. 109–117, pls. 8,15,17,20,21), from Spitzbergen is the only other species assigned to Kraicz's largely overlooked genus *Roemeripora* and is of special interest as the only other Permian, ceroid syringoporoid. The corallite walls of *R. wimani* are not thickened in the mature region. There are well developed dissepiments and septa are absent, thus distinguishing *R. wimani* from *Bayhaium*.

BAYHAIUM MERRIAMORUM, n. sp.
Pl. 19, figs. 1–6

Description.—Corallum massive, ramose, predominantly ceroid, holotype a fragment approximately 60 mm. in diameter and 90 mm. long. Corallites prismatic to cylindrical (very few), sharply differentiated into mature and immature portions, diverge approximately 20° from axis of corallum in immature region, turn sharply at base of mature region to meet surface of corallum at right angles. Corallites 1–2.5 mm. in diameter, calices average 1.3 mm. deep, ranging from 1 to 2 mm., corallites of isolated phaceloid areas generally approximately 1.5 mm. apart, maximum separation 4 mm. Walls composed of a single layer of prismatic crystals perpendicular to the wall, a dark zone marks line of separation between walls of adjacent corallites; walls approximately 0.2 mm. thick in immature regions, thickening to approximately 0.7 mm. (0.5–1.0 mm.) in mature region by accretion of sclerenchyme. Tabulae complete, infundibuliform

and spaced 1–3 per mm. in immature region, infundibuliform to concave in mature region and less closely spaced, tabulae average 0.1 mm. thick in mature region, slightly thinner in immature region. Twenty-four septa in mature region only, represented by sclerenchymal ridges, sclerenchymal septa coalesce to form layers of collar-like constrictions of the corallites at common levels parallel to the surface of the corallum. Irregularly spaced, tunnel-like connections between corallites, tabulae deflected to form funnel-like passages to and in some instances through interconnecting tunnels. No axial structure or axial tube.

Documentation.—Holotype 37683 and Hypotypes 37684 and 37685 are in the collections of the Museum of Paleontology, University of California, Berkeley. Approximately fifty colonies or fragments of colonies were available for study and twenty-six thin sections were examined.

Name.—The specific name is in honor of John C. Merriam, developer of the Department of Paleontology at the University of California, and his son, Charles W. Merriam, student of western Paleozoic faunas.

Age and occurrence.—Lower and middle McCloud limestone, Wolfcampian of Shasta County, California. All specimens were obtained from University of California Museum of Paleontology locality B-2044 from the McCloud limestone on the south side of the road at the saddle in the SE corner of section 3 and SW corner of section 2, T33N, R4W, Redding 15 minute quadrangle, edition of 1946, Shasta County, California. This locality is immediately west of Leland Stanford Junior University locality 776 and is stratigraphically below it (Thompson, Wheeler and Hazzard, 1946, p. 23,36, fig. 3).

CONCLUSIONS

Bayhaium is assigned to the Syringoporinae because of its strongly infundibular tabulae and because its general morphologic character more closely resembles that of *Roemeria* and *Roemeripora* than any other genera. In this connection, however, it must be emphasized that these three genera form a homogeneous group of ceroid syringoporoids that might conveniently be separated from the remaining syringoporoids according to present standards of classification.

The fact that sclerenchyme and numerous poorly-defined septa appear in the mature portions only of corallites of *Lyopora* and *Bayhaium* poses an interesting problem. *Lyopora* is confined to Ordovician and Silurian rocks, which means that there are either undiscovered Middle Paleozoic corals with these characters or that the characters have arisen independently in both corals. Similarly, there either must be undiscovered Middle and Late Paleozoic ceroid syringoporoids intermediate between the Devonian *Roemeria* spp. and the Permian *Bayhaium merriamorum* and *Roemeripora wimani* or the ceroid habit must have developed independently among Devonian and Permian syringoporoids.

Finally, the fact that distal thickening of the walls is now known in both the Pachyporinae and Syringoporinae leads to reservations as to the phylogenetic significance of this character.

LITERATURE CITED

ETHERIDGE, ROBERT, JR., 1891, A monograph of the Carboniferous and Permocarboniferous invertebrata of New South Wales. Part 1—Coelenterata: Mem. Geol. Survey New South Wales, Paleontology, no. 5, 64 p., pls. I–XI.

——, 1914, Western Australian Carboniferous fossils, chiefly from Mount Marmion, Lennard River, West Kimberly: Geol. Survey Western Austr., Bull. 58, 59 p. VII pls.

GERTH, HEINRICH, 1921, Die Anthozoën der Dyas von Timor: Palaeont. von Timor, Lief. IX, p. 67–147, taf. CXLV–CL, 12 text-figs.

HEHENWARTER, EKKEHARD, 1951, Ergänzungen zur Tabulatenfauna des Perm von Timor und zur Stellung des Genus *Trachypsammia* Gerth: Palaeontographica, Supp. Band IV, Abt. V, Lief. 2, p. 60–93, pls. IV–VI.

HERITSCH, FRANZ, 1939, Die Korallen des Jungpälaozoikums von Spitzbergen, Arkiv für Zool., Band 31A, no. 16, p. 1–138, taf. I–XXI.

HILL, DOROTHY, 1937, The Permian corals of Western Australia: Royal Soc. Western Austr., Jour., v. 23, p. 43–64, pl. 1, text-figs. 1–11.

——, 1942, Further Permian corals from Western Australia: Royal Soc. Western Austr., Jour., v. 27, p. 57–75, pls. 1,2.

HILL, DOROTHY & STUMM, E. C., 1957, Tabulata *in* BAYER, F. M., AND OTHERS, Part F. Coelenterata: Treatise on Invertebrate Paleontology, R. C. Moore, editor, p. 444–477, text-figs. 340–357, Lawrence, Kansas, Univ. Kansas Press and Geol. Soc. America.

HINDE, G. J., 1890, Notes on the palaeontology of

Western Australia. 2. Corals and Polyzoa; Geol. Mag., p. 194–204, pls. VIII,VIIIa.

KRAICZ, ISA, 1934, Die systematische Stellung von *Roemeria bohemica* Barrande: Lotos, Band 82, p. 38–42, taf. III.

LECOMPTE, MARIUS, 1936, Revision des tabulés Dévoniens décrits par Goldfuss: Mus. Royal Hist. Nat. Belg., Mem. 75, 111 p., 14 pls.

——, 1939, Les tabulés du Dévonien Moyen et Superieur du bord sud du Bassin de Dinant: Mus. Royal Hist. Nat. Belg., Mem. 90, 227 p., XXIII pls.

——, 1952, Madréporaires Paléozoïques *in* PIVETEAU, JEAN, & OTHERS, Traité de Paléontologie, Tome I—Les stades inférieurs d'organisation du Règne animal, Introduction—Généralités—Protistes—Spongiaires—Coelentérés—Bryozoaires: p. 419–538, text-figs. 1–75, Paris, Masson et Cie.

MEEK, F. B., 1864, Description of the Carboniferous fossils: Calif. Geol. Survey, Paleontology, v. 1, p. 1–16, pls. 1,2.

MILNE-EDWARDS, H., & HAIME, JULES, 1854, A monograph of the British fossil corals: lxxxv +322 p., 72 pls., London, Palaeontographical Soc.

MINATO, MASAO, 1955, Japanese Carboniferous and Permian corals: 202 p., 25 text-figs., 43 pls., Tokyo, The Japan Society for the Promotion of Science.

MOORE, R. C., & JEFFORDS, R. M., 1945, Description of Lower Pennsylvanian corals from Texas and adjacent states: Univ. Texas Pub. 4401, Contr. Geology, 1944, p. 76–209, pl. 14, 214 text-figs.

NICHOLSON, H. A., 1899, On the relations between the genera *Syringolites*, Hinde, and *Roemeria*, Edwards and Haime, and on the genus *Caliapora*, Schlüter: Geol. Mag., v. 26, no. 10, p. 433–438, text-figs. 1–5.

OKULITCH, V. J., 1950, Part II. Descriptions of Ordovician tetracorals *in* BASSLER, R. S., Faunal lists and descriptions of Paleozoic corals: Geol. Soc. America Mem. 44, p. 253–315, pls. 1–20.

ROTHPLETZ, F. A., 1892, Die Perm-, Trias- und Jura-Formation auf Timor und Rotti im indischen Archipel.: Palaeontographica, Band 39, p. 57–106, taf. IX-XIV.

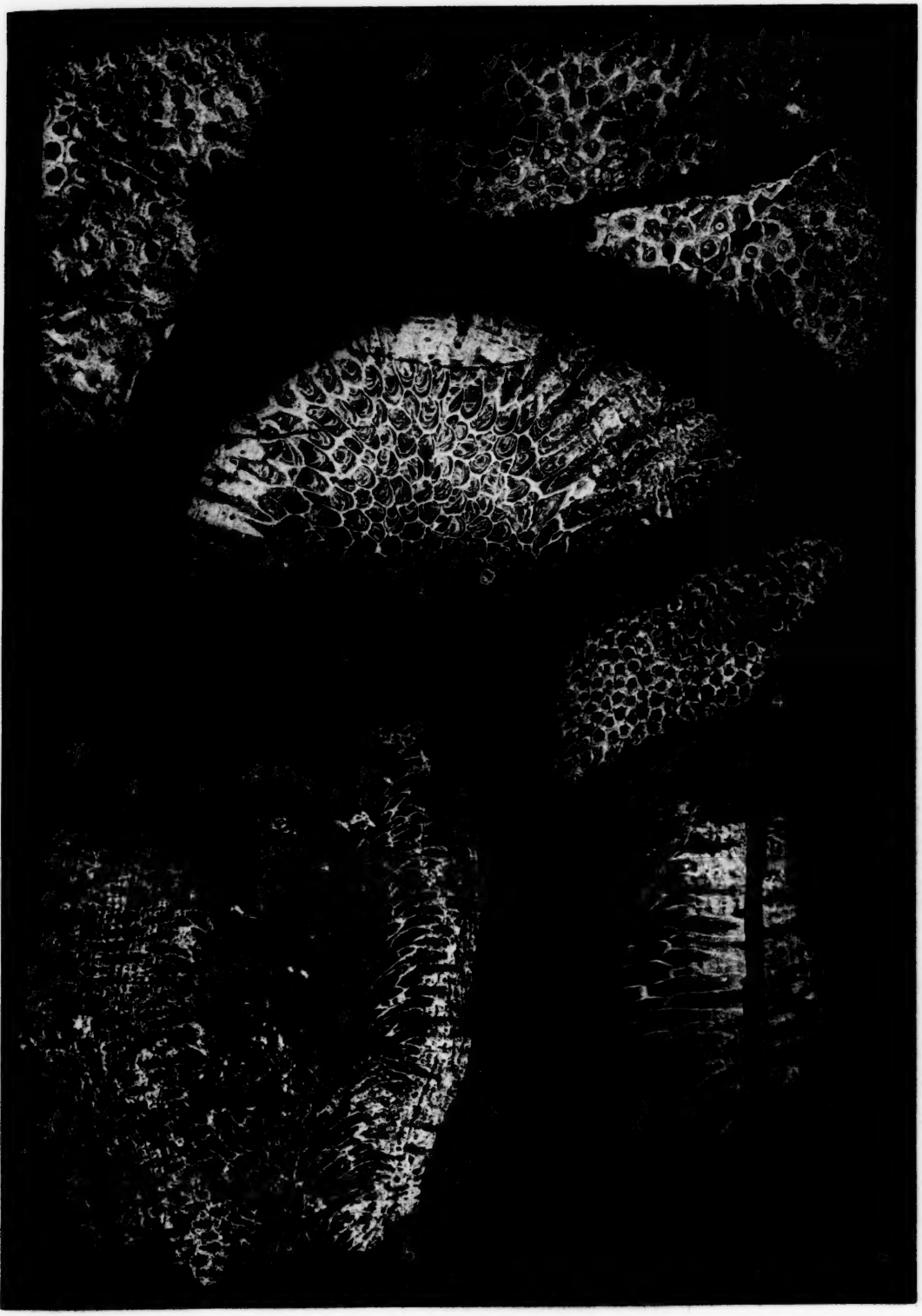
THOMPSON, M. L., WHEELER, H. E., & HAZZARD, J. C., 1946, Permian fusulinids of California: Geol. Soc. America Mem. 17, v+77 p., 18 pls., 4 text-figs.

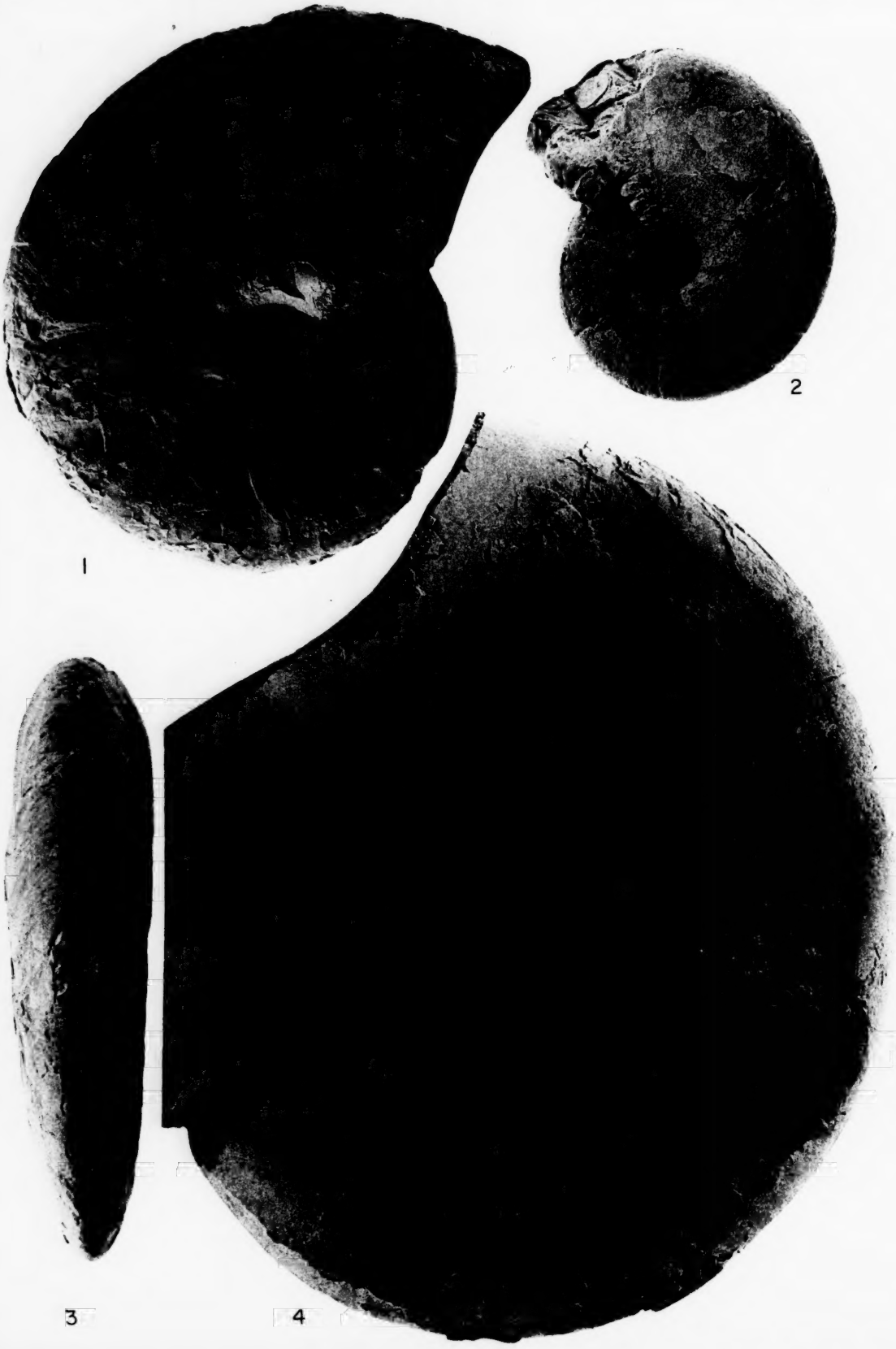
TRIPP, KARL, 1933, Die favositen Gotlands: Palaeontographica, Band 79, Abt. A, p. 75–142, taf. VII–XVI, 53 text-figs.

MANUSCRIPT RECEIVED JULY 23, 1958.

EXPLANATION OF PLATE 19

FIGS. *1–6—Bayhaium merriamorum, n. sp., 1*, tangential section of hypotype UCMP 37684 showing septa at their best development in the mature region, ×2.2; *2*, tangential section of holotype UCMP 37683 showing distinction between walls and sclerenchymal thickening in the mature region, ×1.8; *3*, transverse section of holotype UCMP 37683 showing transverse sections of immature corallites and longitudinal sections of mature corallites, ×1.8; *4*, characteristic weathered surface of hypotype UCMP 37685 showing a few phaceloid corallites, ×1.5; *5*, natural longitudinal section of holotype UCMP 37683 showing layered sclerenchyme and septa in the mature region contrasted with the thin walls of the immature region, ×1; *6*, longitudinal section of holotype UCMP 37683 showing mature and immature corallites, note tunnel-like connections between corallites approximately in the center of the mature region, ×1.8.




1
2
3
4

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 103–105, PL. 20, 5 TEXT-FIGS., JANUARY 1959

NEW AMMONITES FROM THE ALBIAN OF NORTHERN CALIFORNIA

MICHAEL A. MURPHY AND PETER U. RODDA
University of California, Riverside

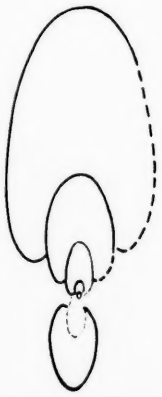
ABSTRACT—Two species of ammonites, which are relatively abundant and are zonal indices, are described in order that the names may be used in stratigraphic discussions of the Albian rocks of Northern California.

Family DESMOCERATIDAE
Genus DESMOCERAS Zittel, 1884
Subgenus PSEUDOUHLIGELLA
Matsumoto, 1942
DESMOCERAS (PSEUDOUHLIGELLA)
VETUS, n. sp.
Pl. 20, fig. 3; text-figs. 1,2

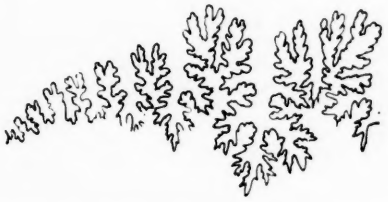
Desmophyllites sp., MURPHY, 1956, p. 2115, fig. 6.

Shell medium size, compressed, involution about 80 percent; ornamentation of biconvex growth lines and very slight peripheral ridges that reflect the constrictions of the internal mold, shell smooth between but with a slight development of ribs on the periphery in some specimens; biconcave constrictions frequent (8 or 9 per whorl); suture slightly retracted with 7 auxiliary lobes in the suspensive lobe; umbilical wall low, rounded, turned under at the umbilical seam; umbilical wall merges imperceptibly with the flank.

Holotype.—The holotype, specimen number 31000 in the U.C.L.A. Invertebrate Paleontology Catalogue, was found at U.C.L.A. locality 3103 (see Murphy, 1956, fig. 5) on Huling Creek. The locality is in a small gully cut along the dip slope of a thick-bedded graywacke which forms a narrows in the stream bed at this point. The fossils at this locality occur in dense limestone nodules which are colored orange on the weathered surfaces. Dimensions of the holotype: at 55 mm. diameter, height of whorl 27 mm.,



TEXT-FIG. *1*—Outline drawing of cross section of *Desmoceras* (*Pseudouhligella*) *vetus*, n. sp., made with the aid of a vertical opaque projector. Natural size.



TEXT-FIG. *2*—Suture line of *Desmoceras* (*Pseudouhligella*) *vetus*, n. sp., made with the aid of a camera lucida. Twice natural size.

EXPLANATION OF PLATE 20

FIGS. *1,3,4*—*Cleoniceras susukii*, n. sp. *1,3*, lateral and ventral views of the paratype, a small specimen, illustrating the development of the ribs; natural size. *4*, lateral view of the holotype showing the funnel-shaped umbilicus and almost complete lack of ornamentation on the mature specimens; about ¾ natural size.

2—*Desmoceras* (*Pseudouhligella*) *vetus*, n. sp. Lateral view of the holotype. Most of the outer shell is gone showing the biconvex pattern of the constrictions.

width of whorl 21 mm., diameter of umbilicus 10 mm.

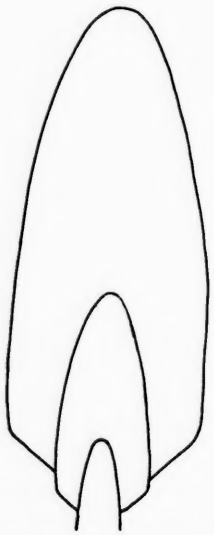
Remarks.—This species differs from other California species (mostly undescribed) in having a much wider umbilicus. The Japanese species *D.* (*P.*) *japonicum* Yabe has a high umbilical wall and a definitely angular umbilical edge. *D.* (*P.*) *vetus*, n. sp., differs from *D.* (*P.*) *ezoanum* Matsumoto in having frequent constrictions and a wider umbilicus.

This species occurs in the lower part of the *hulenana* zone of Murphy (1956, fig. 25, p. 2115) and occurs with *Beudanticeras haydeni* (Gabb) and *Mortoniceras* sp.

The trivial name is from the Latin *vetus*, old.

Family HOPLITIDAE
Genus CLEONICERAS Parona & Bonarelli, 1896
CLEONICERAS SUSUKII, n. sp.
Pl. 20, figs. 1,3,4; text-figs. 3,4

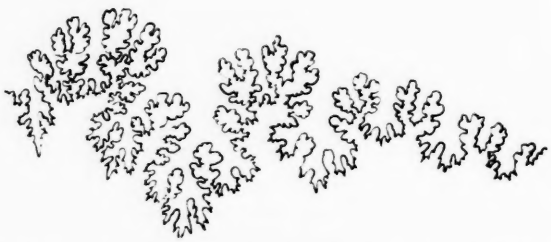
Shell medium to large, compressed, 89 to 90 percent involute; ornamentation of prominent falcoid growth lines and broad low ribs that are present on the peripheral half of the flank but do not cross the venter and are virtually indistinguishable on the inner half of the flank, the body whorl on large specimens is almost smooth; umbilical edge angulate, wrinkled by bulla-like swellings in the younger stages of growth; umbilical wall sloping, overlaps the umbilical wall of the previous whorl in later stages making umbilicus conical or funnel-shaped; venter acutely rounded in youthful stages, more broadly rounded in adult; suture with ventral lobe wide, shallow, first lateral saddle with three major branches, lateral lobe wide, asymmetrically bifid with its ventral auxiliary undercutting the first lateral saddle and much smaller than the dorsal auxiliary.



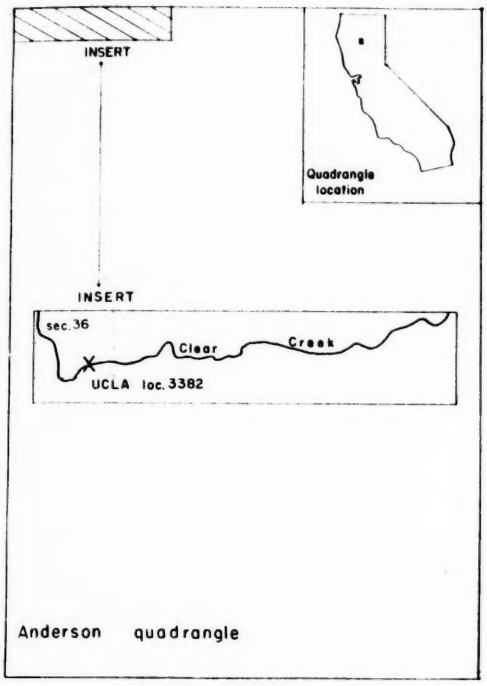
TEXT-FIG. 4—Outline drawing of cross section of a small specimen of *Cleoniceras susukii*, n. sp. Natural size.

Type specimens.—The holotype and paratype, specimen numbers 31001 and 31002, respectively, in the U.C.L.A. Invertebrate Paleontology Catalogue, were collected at U.C.L.A. locality 3382 on Clear Creek (see figure 5). Dimensions of the holotype: at 197 mm. diameter, height of whorl 110 mm., width of whorl about 43 mm., umbilicus 37 mm. diameter at the umbilical edge.

Remarks.—*Cleoniceras susukii*, n. sp., closely resembles d'Orbigny's figures (1842, pl. 84, figs. 1,2) of the genotype, *C. cleon* (d'Orbigny), except that the conch is much



TEXT-FIG. 3—Suture line of *Cleoniceras susukii*, n. sp., made with the aid of a vertical opaque projector. Natural size.



TEXT-FIG. 5—Index map showing the type locality for *Cleoniceras susuki*, n. sp.

larger and the suture much more complexly frilled (probably because of the larger size). Also the ribs of *C. susukii*, n. sp., are not so distinct on the inner half of the flank as in d'Orbigny's figure. Spath's *Cleoniceras aff. C. cleon* (d'Orbigny) (1925, p. 91, pl. 5, fig. 8) has vertical umbilical wall, *C. susukii* n. sp. has a sloping umbilical wall as shown in text figure 4.

This species occurs in the *packardi* zone of Murphy (1956, fig. 5, p. 2115) and occurs with *Oxytropidoceras packardi* Anderson, *Puzosia aldersona* Anderson and *Douvilleiceras restitutum* Anderson.

This species is named for Mr. Takeo Susuki, Museum Paleontologist at the University of California, Los Angeles.

REFERENCES

MURPHY, M. A., 1956, Lower Cretaceous stratigraphic units of northern California: Bull. Am. Assoc. Petroleum Geologists, v. 40, no. 9, p. 2098–2119.

D'ORBIGNY, Z., 1840–1842, Paleontologie francaise. Terrains cretaces. Volume I. Cepahlopodes. Paris.

SPATH, L. F., 1925, A monograph of the Ammonoidea of the Gault: Palaeontographical Soc., London.

MANUSCRIPT RECEIVED JULY 16, 1958.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 106–119, PLS. 21,22, 2 TEXT-FIGS, JANUARY 1959

TRILOBITES FROM THE PEERLESS AND MANITOU FORMATIONS, COLORADO[1]

ROBERT R. BERG AND REUBEN JAMES ROSS, JR.
Cosden Petroleum Corporation, Denver, Colorado; U. S. Geological Survey, Denver, Colorado

ABSTRACT—An Upper Cambrian fauna of Franconian age is present in the Peerless formation in a unit of sandy glauconitic dolomite that formerly was called the Ute Pass dolomite. This fauna includes species of *Idahoia*, *Ellipsocephaloides*, and *Ptychaspis*. The overlying Manitou formation contains in its basal portion species of four lowermost Ordovician zones of Utah (Ross, 1951; Hintze, 1952): the B, C, D, and E or F zones. Sixteen species are described, two of which are new. Distribution of the zones suggests that the Manitou formation is older in the north part of the outcrop area and overlaps the truncated Upper Cambrian rocks from north to south.

INTRODUCTION

THE original purpose of this study was to present a summary of all available fossils that had been collected from the Manitou formation in its type area of central Colorado and previously named only in faunal lists. Berg assembled the known collections, compared the older ones with those made more recently, and found the trilobites distributed in zones conforming to those established by Ross (1951) in the Lower Ordovician of Utah.

As a result of field work by Berg and Ross in 1952 and 1957 in the Manitou Park area, it was determined that the Cambrian beds between the Sawatch quartzite and Manitou formation are correlative with the Peerless formation and similar to it in lithology.

Only trilobites are described in this paper. Gastropods and brachiopods from the Manitou have been sent to B. F. Howell for identification, and the description of these species will be published at a later date.

ACKNOWLEDGMENTS

We are indebted to those who have allowed us to study collections made before 1951: P. E. Cloud, Jr., U. S. Geological Survey, Don Gould, formerly of Colorado College, J. H. Johnson, Colorado School of Mines, and B. F. Howell, Princeton University. Ogden Tweto, U. S. Geological Survey, with Ross revisited sections of the Peerless formation near Pando, Colorado, in September 1957.

[1] Publication authorized by the Director, U. S. Geological Survey.

PEERLESS FORMATION

In 1932 Behre (p. 58) proposed that the term Peerless shale member be applied to the upper part of the Sawatch quartzite in the Weston Mining district north of Leadville, Colorado, 75 miles west northwest of the type area of the Manitou formation. The subject interval had been called "the transition shale" or the "red cast beds." Tweto (1949, p. 161) followed Singewald (1947) in considering the unit a separate formation, "easily distinguished from the Sawatch quartzite in an extensive area northwest of Leadville."

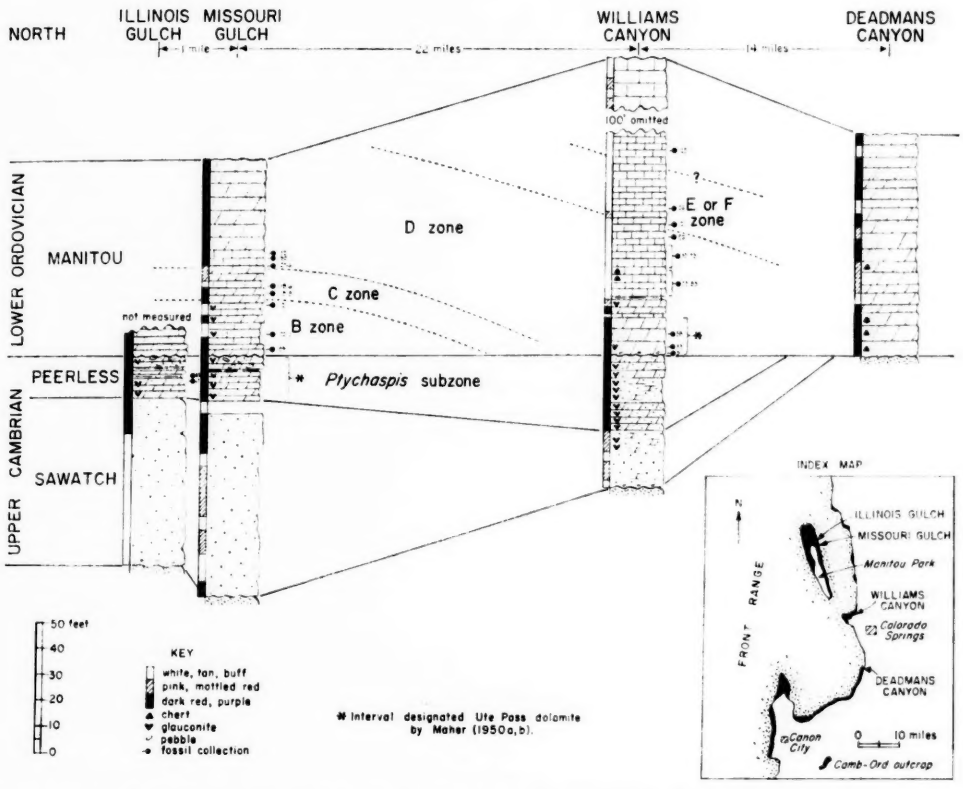
Tweto (1949, p. 162–163) further noted that in the Pando area north of Leadville, the Peerless formation "comprises about 100 feet of dolomitic sandstone, sandy dolomitic shale and dolomite which weathers dark brown or brownish maroon." The dolomitic rocks are buff, tan, green, pink, and maroon and many of them are mottled in various combinations of these colors. Some beds contain edgewise conglomerate. These and numerous problematic borings and trails have a maroon or lighter red color and have been called "red casts" (Behre, 1953, p. 27)

The lower portion of the Peerless formation at two sections measured by Tweto (1949) contains strata similar to those between the Sawatch quartzite and Manitou formation in Illinois and Missouri Gulches, Dakan Mountain quadrangle. This lower portion is the lower 33 feet of the section 2.3 miles north of Pando and the lower 45 feet in the section 2.75 miles north of Pando (Tweto, 1949, p. 164–165).

Few fossils have been collected from the Sawatch quartzite and Peerless formations and their ages have never been certain within the Cambrian. The older Sawatch contains "*Dicellomus* of the *pectenoides* and *nanus* types, both 'lower' Dresbachian" (W. C. Bell, written communication, 10/21/57). The age of the Peerless seems to range from middle Franconian to Trempeleauan.

Johnson (1934, p. 20–21) noted the highly variable nature of the Peerless formation; sections reported by him near Leadville and Alma lack the lower dolomites found near Pando. Trilobites identified by Resser were stated to be *Tellerina*, *Saukia*, and *Briscoia*. In 1942 Resser (p. 66) described and figured *Ellipsocephaloides butleri* from the "Sawatch formation" near Gilman, Colorado. This locality is probably in the Peerless. In the fall of 1957 Tweto, Pearson, and Ross collected a pygidium 44 feet above the base of the formation, 2.75 miles north of Pando (NW¼, SE¼, NE¼, sec. 32, T 6 S, R 80 W). The specimen cannot be accurately identified but it could belong to *Ptychaspis*. In 1950 Josiah Bridge identified another trilobite from very slightly higher in the same section as belonging to the genus *Pterocephalia* (report of identification to Tweto, dated October 4, 1950). Brachiopods from the same collection were identified tentatively by W. C. Bell as *Dicellomus?* cf. "*mosaica*" of the *Conaspis* zone or an unnamed species from the *Cedaria* zone.

At Missouri and Illinois Gulches, in the Manitou Park area (Dakan Mountain quadrangle) (fig. 1), the Peerless formation is represented by dark red dolomite, finely to coarsely granular and rhombic, sandy and glauconitic, and in part cross-bedded. It is



TEXT-FIG. *1*—Columnar sections of the Upper Cambrian and Lower Ordovician formations from which trilobites were collected. The Williams Canyon, Missouri Gulch, and Deadmans Canyon sections are from Maher (1950*b*); the Illinois Gulch section was measured by Berg. Zonal boundaries are shown by dashed lines.

about 16 feet thick. The upper beds are conglomeratic with small discoid pebbles of siltstone; a few thin beds of very fine grained sandstone, siltstone, and gray-green shale are also present. This is the unit referred by Maher (1950*a*, Missouri Gulch section; 1950*b*, p. 18) to the Ute Pass dolomite. In the middle of the Peerless at Illinois Gulch the senior author found *Ptychaspis granulosa* (Owen), *Ellipsocephloides butleri* Resser, and *Idahoia wisconsensis* (Owen). This is a Franconian assemblage of the *Ptychaspis* subzone.

The 14 feet of strata removed from the Manitou formation and designated the type section of the Ute Pass dolomite at Williams Canyon by Maher (1950*a*; 1950*b*, p. 16) is red, finely to coarsely crystalline, compact, and thickly bedded. Though sparsely glauconitic, it is neither sandy nor conglomeratic above the basal 6 inches, and in these respects differs from the more thinly bedded unit at Missouri and Illinois Gulches, called Ute Pass by Maher. Furthermore, the same 14 feet of strata are clearly of Lower Ordovician age (see below) and lithicly comparable to the Manitou formation at other localities (text-fig. 1).

On the basis of faunal correlations, the unit formerly called Ute Pass at Williams Canyon is reassigned to the lower part of the Manitou formation. On the bases of lithology and stratigraphic position, the Ute Pass of Missouri Gulch is correlated by the authors with the Peerless formation. It is recommended, therefore, that the term Ute Pass dolomite be abandoned.

MANITOU FORMATION

The Manitou formation was first described by Cross (1894, p. 2) and named for exposures at Manitou Park and Manitou Springs in the Colorado Springs quadrangle (fig. 1), without specifying a type section. Richardson (1915, p. 4) and Findley (1916, p. 6) assigned an Ordovician age to the formation on the basis of fossils and stratigraphic position; the former mentioned the type section as lying 12 miles south of exposures in sec. 8, T. 12 S., R. 67 W. This was the first mention of a type section, and it was obviously near Manitou Springs in Richardson's opinion. With this Findley agreed (1916, p. 6).

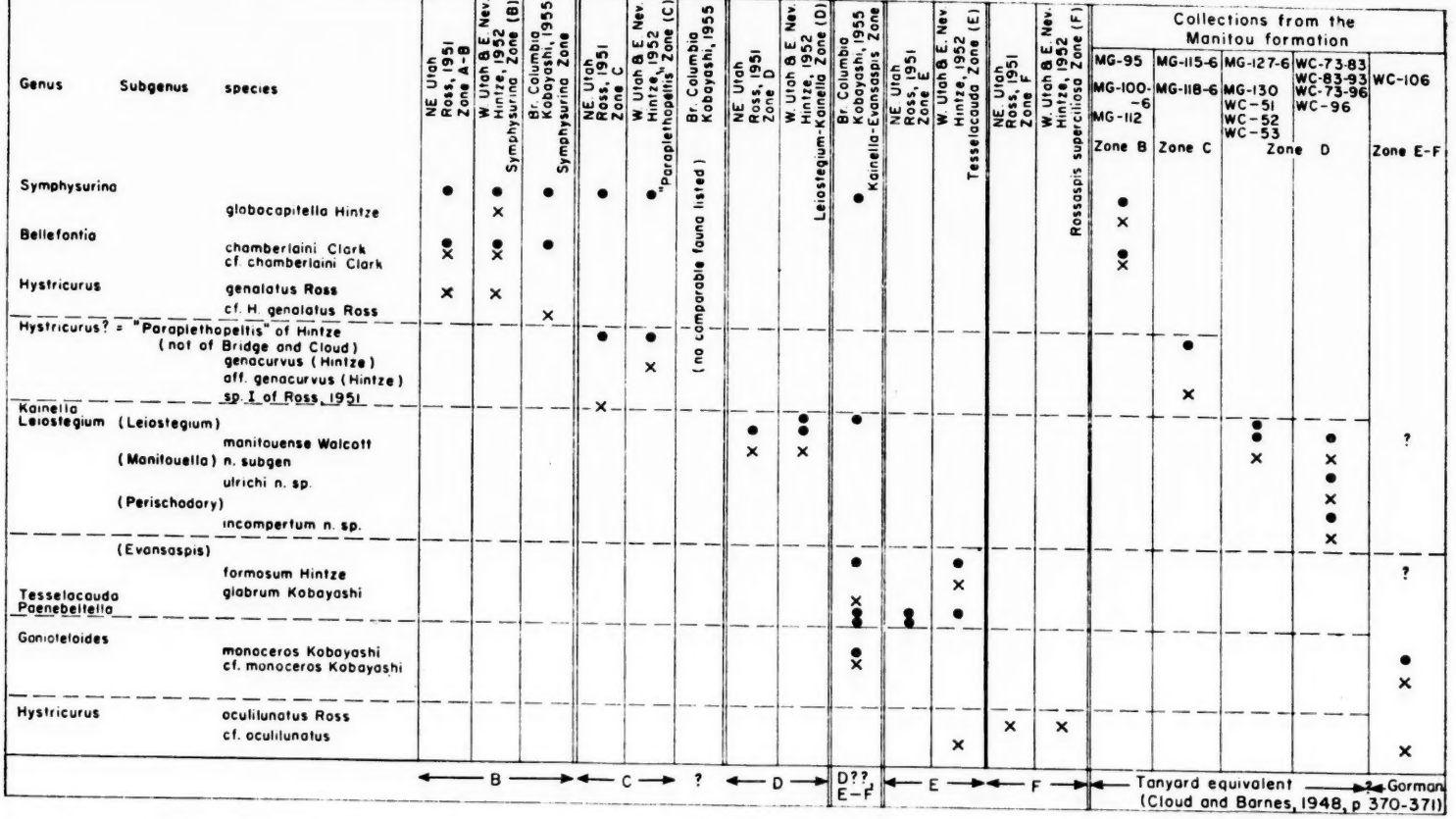
Brainerd, Baldwin, & Keyte (1933, p. 380) formally designated the section in Williams Canyon on the northern outskirts of Manitou Springs as the type for the Manitou limestone. There they recognized the Devonian Williams Canyon formation and Mississippian limestone, strata of which had previously been included in the Manitou limestone. Cloud & Barnes (1948, p. 76, 369–371) described and measured the type section and collected Lower Ordovician fossils from it.

Prior to 1930 trilobites were collected by T. W. Stanton, I. A. Keyte, and C. E. Resser. These were deposited in the U. S. National Museum and at Colorado College, Colorado Springs, but only one species, *Leiostegium manitouensis*, was described (Walcott, 1925, p. 104). Don B. Gould, with students at Colorado College, and J. H. Johnson made other collections in 1939.

Separately these collections are sparse and incomplete, but together they add considerably to our knowledge of the Manitou faunas. Their most important components are described here. In 1952 Berg, and in 1954 Ross, collected at the Missouri Gulch and Williams Canyon sections, and identified species that can be correlated with recently described Lower Ordovician faunas of the Great Basin. Although the collections made thus far probably do not represent the entire trilobite fauna, enough specimens are at hand to give a more detailed zonation of the lower part of the Manitou than was heretofore possible. It is hoped that this description of existing collections will aid in regional correlation problems and stimulate further study.

The Manitou formation consists of finely to coarsely crystalline limestone and a minor amount of dolomite that totals 195 feet in thickness at its designated type locality in Williams Canyon (text-fig. 2). Here the section is sparingly fossiliferous and contains a trilobite and brachiopod fauna in the lower part and a gastropod fauna above. To the northwest in Manitou Park, the formation consists chiefly of dense, red dolomite as in the vicinity of Missouri Gulch, and trilobites occur mainly in thin beds of limestone. South of Williams Canyon the Manitou is massive, red dense dolomite, and no fossils have been found.

Trilobites from the basal part of the Mani-



TEXT-FIG. 2—Distribution of trilobite genera (●) and species (×) identified from the Manitou formation compared with distribution in sections in Utah, Nevada, and British Columbia.

tou at Missouri Gulch are species of the lowermost Ordovician and are assigned to the B, C, and D zones as defined recently in Utah by Ross (1951, p. 29) and Hintze (1952, p. 5). At Williams Canyon the lower part of the Manitou contains only the D zone, but in addition the E or F zone occurs higher in the section. Above that Cloud & Barnes (1948, p. 371, collection CF-11) obtained a single badly broken cranidium that may possibly belong to *Pseudoolenoides*. This genus has been reported to date only from zones M and N of the Great Basin (Hintze, 1952, p. 20–23).

The equivalence of the assemblage listed below under zone E to the same zone in the Garden City formation is suggested by the following: *Hystricurus oculilunatus* is typical of zone F (Ross, 1951, p. 28; Hintze, 1952, p. 11), but it has also been found in zone E by Hintze (1952, p. 10). *Gonioteloides* cf. *G. monoceros* was described by Kobayashi (1955, p. 447–448) from the MacKay Group, as an element of his (p. 365–366) "*Symphysurina*" and "*Kainella-Evansaspis* faunas.' These Kobayashi (1955, p. 375) correlated with the B-C and E zones, respectively, of the Garden City formation. The overlap of ranges of these two species falls in zone E (fig. 2).

Central Colorado appears to be one of the few areas in the western United States where there exists a demonstrable erosional break between the Upper Cambrian and Lower Ordovician. Evidence is found in the absence of rocks of Trempeleau age at Williams Canyon and Missouri Gulch (fig. 1), although present in the Mosquito Range (Johnson, 1934, p. 20–21). Quartz and feldspar pebbles are present in the basal 6 inches of the Manitou formation at Williams Canyon suggesting that the basement rock was subject locally to erosion in Early Ordovician time. Although distribution of faunal zones may be controlled in part by environment, we believe that the loss of the B and C zone faunas from north to south indicates that the Manitou formation slowly lapped southward over the eroded pre-Ordovician surface. From north to south it rests successively on the Peerless formation, the Sawatch quartzite, and Precambrian rocks. In fact the Manitou rests on Precambrian rocks in most of Fremont County, southern Park County, the southern half of Chaffee County and northeastern Saguache County (Sweet, 1954, fig. 4). It is in turn overlapped by the Middle Ordovician Harding sandstone which rests on the Precambrian at least as far south as Beulah in southwestern Pueblo County and Crestone in eastern Saguache County.

ALTERNATE INTERPRETATION

The possibility has been considered that the Peerless and Sawatch equivalents shown on text-figure 1 at Williams Canyon are younger than at Missouri Gulch and that part of the Peerless may actually be of Ordovician age to the south. No fossils are available from the critical interval. On the basis of similarity of lithology and stratigraphic position it compares most closely with known Cambrian. When regional stratigraphy is considered an unconformity between Peerless and Manitou formations, as indicated in text-figure 1, seems the best explanation of the known facts.

LOCALITIES

Localities from which collections were obtained are shown in text-figure 1, and a description of each collection is given below in descending order. Collections are designated by locality initials followed by a number indicating the elevation in feet and inches above the base of the measured section. Measurements refer to the detailed sections published by Maher (1950*b*), except for Illinois Gulch. Most of the collections were made by Berg, but at Williams Canyon, older collections are included. These are credited in parentheses to the following collectors: "CF" numbers are Cloud & Barnes (1948, p. 371); "S" numbers are T. W. Stanton, 1921; "K" numbers are I. A. Keyte, date unknown; and "J&G" numbers are J. H. Johnson and D. Gould, 1939. "D" numbers are collections by Ross, 1955.

The occurrence of genera and species of the Manitou formation and a few others needed for interregional correlation, is shown in text-figure 2. This indicates evidence for zonal arrangement.

Illinois Gulch. Exposures of Peerless formation along trail in W½ section 27, T. 10 S., R. 69 W., Douglas Co.

Ptychaspis subzone
IG-68
Ellipsocephaloides butleri Resser
Idahoia wisconsensis (Owen)
Ptychaspis granulosa (Owen)
IF-67
Idahoia sp.

Missouri Gulch. Quarry in Manitou formation in E½, section 34, T. 10 S., R. 69 W., Douglas Co.
Zone D
MG-132 (D196a€O)
Leiostegium (*Leiostegium*) *manitouensis* Walcott
Kainella sp.
MG-130, MG-127-6
Leiostegium (*Leiostegium*) *manitouensis* Walcott
Zone C
MG-118-6, MG-115-6
Hystricurus? aff. *H.? genacurvus* (Hintze)
Zone B
MG-112
Bellefontia cf. *B. chamberlaini* Clark
MG-100-6, MG-95
Symphysurina cf. *S. globocapitella* Hintze

Williams Canyon. Exposures in NW¼ section 32, T. 13 S., R. 67 W., El Paso Co.
WC-129 (CF-11)
Pseudoolenoides?
Zone E or F
WC-106 (CF-9)
Hystricurus oculilunatus Ross
Gonioteloides cf. *G. monoceros* Kobayashi
Leiostegium sp.
Undet. pygidum No. 1
Undet. pygidium No. 2
Zone D
WC-96
Leiostegium (*Manitouella*) *ulrichi* n. sp.
WC-73-96 (K254p)
Leiostegium (*Manitouella*) *ulrichi* n. sp.
WC-83-93 (S496R3), WC-73-83 (S496R1)
Leiostegium (*Perischodory*) *incompertum* n. sp.
Leiostegium (*Leiostegium*) *manitouensis* Walcott
WC-58 (J&G 12), WC-53 (CF-5), WC-51 (J&G 8–10) (D198€O)
Leiostegium (*Leiostegium*) *manitouensis* Walcott

SYSTEMATIC DESCRIPTIONS

CAMBRIAN TRILOBITES

Genus ELLIPSOCEPHALOIDES Kobayashi, 1935

ELLIPSOCEPHALOIDES BUTLERI Resser

Pl. 22, fig. 8

Ellipsocephaloides butleri RESSER, 1942, p. 66, pl. 11, figs. 14,15.

Numerous casts of small, flattened cranidia occur on silty partings in the Peerless formation. The glabellar form, short frontal area, and well-defined palpebral lobes suggest assignment to *E. butleri*, one of eleven species described by Resser (1942, p. 62–67) It is similar to *E. gracilis* from Minnesota, and as pointed out by Feniak (Bell, Feniak, & Kurtz, 1952, p. 188) most of the Resser species eventually may be recognized as conspecific.

Figured specimen.—USNM 136398.

Locality.—IG-68.

Discussion.—The type specimen came from the Upper Cambrian near Gilman, Colorado, probably from the Peerless formation. In the Upper Mississippi Valley, *E. gracilis* occurs in the *Prosaukia* subzone, but at Illinois Gulch, the associated species described below indicate the *Ptychaspis* subzone of the Franconian stage.

Genus IDAHOIA Walcott, 1924

IDAHOIA WISCONSENSIS (Owen)

Pl. 22, fig. 10

Crepicephalus? wisconsensis OWEN, 1852, tab. 1, fig. 13.

Idahoia wisconsensis (OWEN). BELL, FENIAK, & KURTZ, 1952, p. 189, pl. 37, figs. 3a–f (for complete synonymy).

The species is represented by one specimen, a poor cranidial cast in siltstone. Only the glabella and long occipital spine are distinct, but the exceptional width of the faintly preserved frontal area suggests the presence of strongly divergent facial sutures anterior to the palpebral lobes. The width of the border appears to be about one-half that of the brim.

Figured specimen.—USNM 136399.

Locality.—IG-68.

Discussion.—This species occurs in the *Ptychaspis-Prosaukia* zone of the Upper Mississippi Valley Franconian.

IDAHOIA sp.

Pl. 22, figs. 7,11

Two small, fragmentary cranidia appear to be a species of *Idahoia*. The general convexity of the cranidium and a long frontal area having a convex downsloping brim and flat border, bears some resemblance to *I. hera* (Walcott). One cranidium (fig. 10) has a thickening of the central occipital ring suggestive of a spine base, a wide frontal area, and evidence of narrow posterior limbs.

Figured specimens.—USNM 136400, 136401.

Locality.—IG-67.

Genus PTYCHASPIS Hall, 1863

PTYCHASPIS GRANULOSA (Owen)

Pl. 22, fig. 12

Dikelocephalus granulosa OWEN, 1852, tab. 1, figs. 5,7.

Ptychaspis granulosa (OWEN). BELL, FENIAK, & KURTZ, 1952, p. 193, figs. 6a–b, pl. 35, figs. 1a–e (for complete synonymy.)

One pygidium is assigned to this species. Although flattened, its form is identical to pygidia figured by Bell, Feniak, and Kurtz (1952). The wide axis consists of five segments, and its width is about one-fourth that of the pygidium. Pleural segments are not well preserved.

Figured specimen.—USNM 136402.

Locality.—IG-68.

Discussion.—This species is characteristic of the *Ptychaspis* subzone, Franconian stage.

ORDOVICIAN TRILOBITES

Genus SYMPHYSURINA Ulrich, 1924

SYMPHYSURINA sp. cf. S. GLOBOCAPITELLA Hintze

Pl. 21, fig. 25; pl. 22, fig. 3

Symphysurina globocapitella HINTZE, 1952, p. 232, pl. 1, figs. 1–9.

One cranidium and two pygidia are known from the Manitou formation. No free cheeks are available, so that final identification is not possible. The axis of the pygidium is a little better defined than on specimens illustrated by Hintze.

Figured specimens.—USNM 136403, 136404.

Locality.—MG-95, MG-100-6.

Discussion.—This species is reported in zone B of the Garden City formation by Hintze.

Genus HYSTRICURUS Raymond, 1913

HYSTRICURUS OCULILUNATUS Ross

Pl. 21, fig. 2

Hystricurus oculilunatus Ross, 1951, p. 47–48, pl. 10, figs. 2,12.

Although both specimens are broken cranidia the outline and convexity of the glabella and crescentic shape of the palpebral rim serve to identify them.

Figured specimen.—USNM 136405.

Locality.—WC-106.

Discussion.—In Utah this species is found in zone "F" of Ross (1951) and Hintze (1952). Here it is associated with *Goniotelvides* cf. *G. monoceros* which Kobayashi (1955, p. 365–366) considers correlative with zones "B" to "E."

HYSTRICURUS? sp. aff. H.? GENACURVUS (Hintze)

Pl. 21, figs. 21,23

Paraplethopeltis? genacurvus HINTZE, 1952, p. 202–204, pl. 7, figs. 1–5.

This species is represented by five cranidia. These show marked differences in the outline of the glabella, which is elongate in one specimen (pl. 21, fig. 23, MG-118-6) and rather broad in another (pl. 21, fig. 21, MG-118-6). Those with the broader outline resemble *P.? genacurvus* Hintze most closely. However, the Manitou specimens seem to have a crest along the glabella on either side of which the slopes are slightly flattened; in this respect they differ from those illustrated by Hintze (1952, pl. 7, figs. 1a, 3c).

Because they lack free cheeks and pygidia, a cogent comparison with the Utah species is impossible.

Figured specimens.—USNM 136406, 136407.

Locality.—MG-115-6, MG-118-6.

Discussion.—Hintze (1952, p. 201–202) has already discussed the problem of assigning trilobites of this kind to a previously known genus. That these and the species to which he referred do not belong to *Paraplethopeltis* is very likely; that genus does not possess eyelines or a distinct border around the front of the cranidium (Bridge & Cloud, 1947, pl. 2, figs. 6,7,10,11,21). Hintze's fear that these features might not appear on the material described by Bridge & Cloud was overcautious.

It is much more difficult to decide to which genus these forms do belong. All have a certain similarity. The glabella is subovoid, in most, slightly compressed. The preglabellar field is convex and separated from a well-developed rim (or border) by a distinct break in slope or marginal furrow. The fixed cheeks are only slightly convex and the palpebral lobes crescentic. The dorsal furrows are deep and continuous around the

front of the glabella. Eye lines are present on most specimens. The list of species which seen to belong in this group was first compiled by Hintze (1952, p. 201–203); it inincludes.

	Zone
Paraplethopeltis? genacurvus HINTZE, 1952, p. 202, pl. 7, figs. 1–5	C
Paraplethopeltis? genarectus HINTZE, 1952, p. 204, pl. 7, figs. 6–9	C
Hystricurus? sp. E, ROSS, 1951, p. 54, pl. 15, figs. 10,11,13,14	?
Hystricurus? sp. I, ROSS, 1951, p. 56, pl. 17, figs. 1–3	C
Pachycranium? sp., ROSS, 1951, p. 73, pl. 17, figs. 4–6,9–11,14,15	C
Hystricurus nudus POULSEN, 1937, p. 34, pl. 2, fig. 10	?

The pygidia are known for the first three listed above. These are sub-semicircular in outline with a prominent axis of five segments. The pleural platforms are flat proximally but convex and very steep distally; there are three to four pairs of pleura on the platforms, each bearing a diagonal groove. A wire-like rim is present. Except for the rim the pygidia resemble closely those of *Paraplethopeltis*, but do not differ significantly from those of *Hystricurus*.

The stratigraphic significance of these trilobites seems to be more apparent than their proper generic assignment. Four of the six listed above are from zone C of the Garden City formation or its equivalents. The positions of the other two are not known. The odds, therefore, strongly favor correlation of the beds in which they occur in the Manitou with zone C. For purposes of this paper that is their great value.

Genus BELLEFONTIA Ulrich, 1924

BELLEFONTIA sp. cf. B. CHAMBERLAINI Clark

Pl. 21, figs. 18,20,22

Bellefontia chamberlaini CLARK, 1935, p. 245, pl. 24, figs. 10,11.

The specimens at hand are poorly preserved but adequate to insure that they closely resemble *B. chamberlaini* Clark. The single cranidium and two pygidia are those of immature individuals, which are characterized by greater convexity than full grown specimens in this genus.

Figured specimens.—USNM 136408, 136409, 136410.

Locality.—MG-112-0.

Discussion.—The importance of this species is as an indicator of a zone correlative with zone B of the Garden City formation.

Genus LEIOSTEGIUM Raymond, 1913

This genus is abundantly represented in the Manitou formation by at least two subgenera and several species. Preservation leaves much to be desired. Most specimens are rough molds in dolomitized rock. A considerable amount of variation is shown by these specimens, but how much is attributable to preservation is uncertain. Three subgenera seem to be present. These are *Leiostegium* (*Leiostegium*), *L.* (*Perischodory*) Raymond, and *L.* (*Manitouella*), n. subgen.

Kobayashi (1955, p. 420) erected the subgenus *Evanaspis* to include all Leiostegiids with a pair of spines "issuing from the lateral border"; the type species was chosen as *L.* (*E.*) *glabrum* Kobayashi (1955, p. 421–422, pl. 2, figs. 11–17) in which the spines are located posterolaterally. Kobayashi placed *Perischodory grandgei* Raymond in *Evansaspis* because it also possesses a pair of spines. However, these are located at the anterior corners of the pygidium.

If the possession of these spines merits subgeneric rank, their position probably is equally important. *Perischodory*, although no cephalic parts are known for the type species, should not be considered a separate genus. However, it is probably as valid a subgenus as *Evansaspis* when the latter is restricted to species like *L.* (*E.*) *glabrum* Kobayashi and *L.* (*E.*) *formosum* Hintze.

In the collection from the Manitou in which *L.* (*Perischodory*) was found, there are pygidia of *Leiostegium* (*Leiostegium*) but we have not been able to distinguish with certainty two distinct cranidia. Either the cranidia of *L.* (*Perischodory*) are essentially the same as those of *L.* (*Leiostegium*) or the small collections by bad luck of the collectors do not include them.

The age significance of *Leiostegium* is not as restricted as Ross (1951) previously thought. Hintze's discovery of *L. formosum* in the "F" zone extended the generic range

out of the "D" zone. Recent work in Nevada shows that the genus is present in the very top of the Goodwin limestone, probably equivalent to the lower "G" zone of the Garden City formation in northeastern Utah. Associated with *Kainella* it still seems to be a good index to the "D" zone. *Kainella*, however, may appear earlier than *Leiostegium*.

In the Manitou formation at Williams Canyon *Leiostegium* (*Leiostegium*) seems to be succeeded by a zone characterized by *L.* (*Leiostegium*) and *L.* (*Perischodory*) and this in turn by a zone containing *L.* (*Perischodory*) and *L.* (*Manitouella*). All three of these may be within zone "D," since species indicative of zone "E" occur above them. Because *L.* (*Leiostegium*) is known to occur above zone "D" it is obvious that this tripartite subdivision cannot be expected to hold elsewhere and may not be valid everywhere within the Manitou itself.

Subgenus LEIOSTEGIUM

LEIOSTEGIUM MANITOUENSIS Walcott

Pl. 21, figs. 10,13,17,24

Leiostegium manitouensis WALCOTT, 1925, p. 104, pl. 23, figs. 12–19.

This species is abundantly represented in the Manitou formation, but its preservation in most cases leaves much to be desired. Comparison of cranidia illustrated here (pl. 21, figs. 10,11) gives some idea of the real and/or apparent variation exhibited. That in plate 21, figure 11, MG 132, retains the outer surface and form of the carapace and compares closely with Walcott's type specimen. The cranidium in plate 21, figure 10, is a dolomitized mold. The low profile and tapering outline of the glabella seem to indicate that it is not *L. manitouensis*. Yet because of the difference in preservation one has no real confidence that it is truly a different species. Both of these specimens differ from the type cranidium (Walcott, 1925, pl. 23, figs. 12–14) in the small size of the palpebral lobes. The cranidium shown in plate 21, figure 19 (496 R 1) is closer to the type in this respect.

Some pygidia seem to be a little narrower than the type specimens (Walcott, 1925, pl. 23, figs. 16,17,19). The lengths of the types are six-tenths their respective widths. Some of the specimens shown here (D196€O, D198CO) are over two-thirds as long as wide. The stratigraphic significance of this difference is uncertain.

Figured specimens.—USNM 136411, 136412, 136413, 136414, 136415, 136416.

Localities.—WC-73-83 (496 R 1), WC-53(CF-5), WC-51, D198€O, D196€O, MG-130, MG-132.

Subgenus PERISCHODORY Raymond, 1937

Perischodory RAYMOND, 1937, p. 1122.
Evansaspis KOBAYASHI, 1955, p. 420–421 (in part)

As in the case of *Perischodory grandgei*, no cephalic parts can be assigned to this subgenus from the Manitou formation. There can be no absolute assurance that the Vermont and Colorado specimens belong to the same subgenus. The pygidia are so very much alike that we believe they do.

Kobayashi (1955, p. 420–421) included *Perischodory* in the subgenus *Evansaspis* because it possesses a pair of lateral spines on the pygidium. However, in *Perischodory* this pair is based at the anterior corners (see pl. 21, fig. 15; plate 22, fig. 4) in a manner quite different from that of the type species of *Evansaspis*. For that reason we propose that *Perischodory* be considered a separate subgenus of *Leiostegium*. If it were not for the lateral spines, the pygidia of both *P. grandgei* and the Manitou specimen would be assigned to *Leiostegium* (*Leiostegium*).

LEIOSTEGIUM (LEIOSTEGIUM) sp.

Pl. 22, figs. 1,2

One cranidium and one pygidium are known for this species. If a larger sample were available it might be possible to determine whether these are large, deformed examples of *L. manitouensis* or a new species.

The cranidium is slightly crushed, and lacks the palpebral lobes. The postero-lateral limbs are fairly long and slender compared to those of other species. There seem to be two pairs of pits in the dorsal furrows and the glabela is sub-rectangular in outline.

The large pygidium is only slightly convex and the marginal furrow faint.

Figured specimens.—USNM 136419, 136420.

Locality.—Near Fish Hatchery, Trout Creek, sec. 21, T. 10 S., R. 69 W., Teller Co.,

Colorado. Stratigraphic position within Manitou formation not known.

Discussion.—The pygidium is less triangular than that of *L. manitouensis;* the marginal furrow and definition of axial rings are much fainter than in other species. These might be features of maturity or of deformation.

Because the exact stratigraphic position of these specimens is unknown and because the sample is too small, these specimens have little stratigraphic value. They are illustrated as a record of the existence of such forms in the Manitou formation.

LEIOSTEGIUM (PERISCHODORY) INCOMPERTUM n. sp.

Pl. 21, fig. 15; pl. 22, fig. 4

This species is known only from pygidia, although some of the associated cranidia may belong to it.

The length of the pygidium is about six-tenths the width, excluding the lateral spines. The length of the axis is eight-tenths that of the pygidium; its width at the anterior end is a quarter that of the pygidium and equal to half its own length. The border or rim is bounded proximally by a shallow marginal furrow. The lateral spines are based in the border, there being no deflection of the marginal furrow at their proximal ends. There are at least five well-developed rings at the front of the axis.

Types.—Holotype; USNM 136421; paratype, USNM 136422.

Locality.—496 R 1.

Discussion.—Two associated cranidia are illustrated (pl. 21, figs. 14,19); one or the other or both of these may belong to this species or to *Leiostegium* (*Leiostegium*) *manitouensis,* which is also present. One of the cranidia seems to have a more quadrate glabella than the other and this may eventually prove to be an interspecific difference.

This species is twice as large as *L.* (*P.*) *grandgei* Raymond, if the latter's holotype is typical in size. Excluding the lateral spines the pygidium has the same relative proportions as that of *L.* (*L.*) *manitouensis,* but is larger than most specimens of that species.

Subgenus MANITOUELLA, n. subgen.

The specimens of *Manitouella ulrichi* n. sp. described here were to be the types of several species and the basis for erection of the genus *Manitouella* by Ulrich. This is clearly indicated by his notes on labels. We have retained the generic name but the species, which were separated on inconsequential minutiae, we have included in the single species *M. ulrichi.*

The cranidium of *Manitouella* differs from that of *Leiostegium* ss. in the possession of a flattened rim at the front and very faint eyelines. In *Leiostegium* (*Leiostegium*), the rim is raised subtubular, so that there is a distinct marginal furrow. In this subgenus, the rim is separated from the cranidium and fixed cheeks by a break in slope rather than a furrow.

The pygidium of *Manitouella* is very different from those of *L.* (*Leiostegium*) for it lacks a marginal furrow and border and more closely resembles some asaphid types. The outline is semielliptical. The axis is narrow and divided into numerous rings; these may appear faint unless a decorticated specimen is obtained. The axial furrows are well developed. The pleural platforms are smoothly rounded and devoid of furrows.

Type species.—*Manitouella ulrichi,* n. sp.

Discussion.—This subgenus is associated through part of its range with *Perischodory* another subgenus of *Leiostegium.* If our estimate of the exact position of the original collections is correct, this should be a little younger than *Perischodory.*

LEIOSTEGIUM (MANITOUELLA) ULRICHI, n. sp.

Pl. 21, figs. 1,3,4,6; pl. 22, figs. 5,9

Cranidium sub-trapezoidal in outline. Glabella tapering anteriorly. Anterior pits well-developed but shallow. Eye ridges run from dorsal furrows to fronts of palpebral lobes; the point of origin in the dorsal furrow is behind the anterior pit a distance equal to two-tenths the length of the glabella. Eye ridges not distinct on all specimens. Palpebral lobes almost semicircular when preserved; their length (exsagittal) about $\frac{1}{4}$–$\frac{1}{3}$ that of the glabella. The fixed cheeks subrectangular; on a line through the eyes but exclusive of the palpebral lobes each comprises about three-tenths the width of the cranidium.

Pygidium narrowly rounded posteriorly,

USNM Nos.	*136423*	*136424*	*136425*	*136426*
Cranidium:				
Length of cranidium	27.0	20.5	10.0	7.8
Length of glabella	24.5	18.5	9.3	7.5
Width of glabella between anterior pits	15.0	11.0	4.4	4.2
Width of glabella between the eyes	16.5	12.0	5.8	4.7
Width of glabella at occipital ring	18.1	13.0	6.0	5.9
Width of cranidium at palpebral lobes	43.6(?)	32.5		12.3(?)
Width of cranidium at posterolateral limbs	44.5(?)	34.0	—	—
Length of occipital ring	3.5(?)	2.4	1.5	1.0

USNM Nos.	*136427*	*136428*	*136429*
Pygidium:			
Length of pygidium	24.7	19.8	8.0
Width of pygidium	43.2	31.5	13.5
Length of axis	21.5	17.0	7.3
Width of axis	9.0	7.0	3.1
Number of rings in axis	11	*4+	7+

* This specimen not decorticated.

almost semielliptical. Axis very narrow, composed of more than 11 rings; specimens which are not decorticated show only the anterior three or four rings. Pleural platforms smooth. Only the articulating furrow is present at front.

Figured specimens.—USNM 136423–136429.

Localities.—WC-96, 254 p.

Discussion.—Type pygidia of this species closely resemble those assigned tentatively to *Asaphellus? eudocia* by Ross (1951, pl. 27, figs. 17,22,23); those have pleural grooves, however.

EXPLANATION OF PLATE 21

FIGS. *1,3,4,6*—*Leiostegium* (*Manitouella*) *ulrichi* n. subgen., n. sp. Locality 254 p. *1*, paratype, cranidium, ×1. USNM 136424; *3*, holotype, pygidium, ×1. USNM 136428; *4*, paratype, immature pygidium, ×1. USNM 136429; *6*, paratype, cranidium, ×2. USNM 136426.

2—*Hystricurus oculilunatus* Ross. Cranidium, ×2. Locality WC-106 (CF-9). USNM 136405.

5—*Psalikilus paraspinosum* Hintze. Pygidium, ×5, illustrated for comparison with *Goniotecloides*, figs. 8,9, this plate. Garden City formation, zone G(2), 580 feet above base. Locality 6 of Ross (1951, p. 16–17). USNM 136433.

7—Undetermined pygidium No. 1, ×1. Locality WC-106 (CF-9). USNM 136435.

8,9—*Goniotecloides* sp. cf. *G. monoceros* Kobayashi. Dorsal and left lateral views of pygidium, ×1. Locality WC-106 (CF-9). USNM 136434.

10–13,17,24—*Leiostegium* (*Leiostegium*) *manitouensis* Walcott. 10, cranidium, decorticated, natural cast in fine dolomite, ×1. Locality D198 €O. USNM 136411. *11*, cranidium, not decorticated, from limestone matrix, ×1. Locality D196a €O. USNM 136412. *12*, pygidium, decorticated, natural cast in fine dolomite, ×1. Locality MG-130. USNM 136413. *13*, pygidium, not decorticated, from limestone matrix, ×1. Locality D196a €O. USNM 136414. *17*, pygidium, decorticated, natural cast in limestone, ×1. Locality 496 R1. USNM 136415. *24*, pygidium, small, decorticated, natural cast in fine dolomite ×1. Locality D198 €O. USNM 136416.

14,19—*Leiostegium* cranidia; not identified to subgenus or species, ×1. Locality 496 R1. *14*, USNM 136417; *19*. USNM 136418.

15—*Leiostegium* (*Perischodory*) *incompertum*, n. sp. Pygidium, broken, decorticated, natural cast in limestone, ×1. Paratype. USNM 136422.

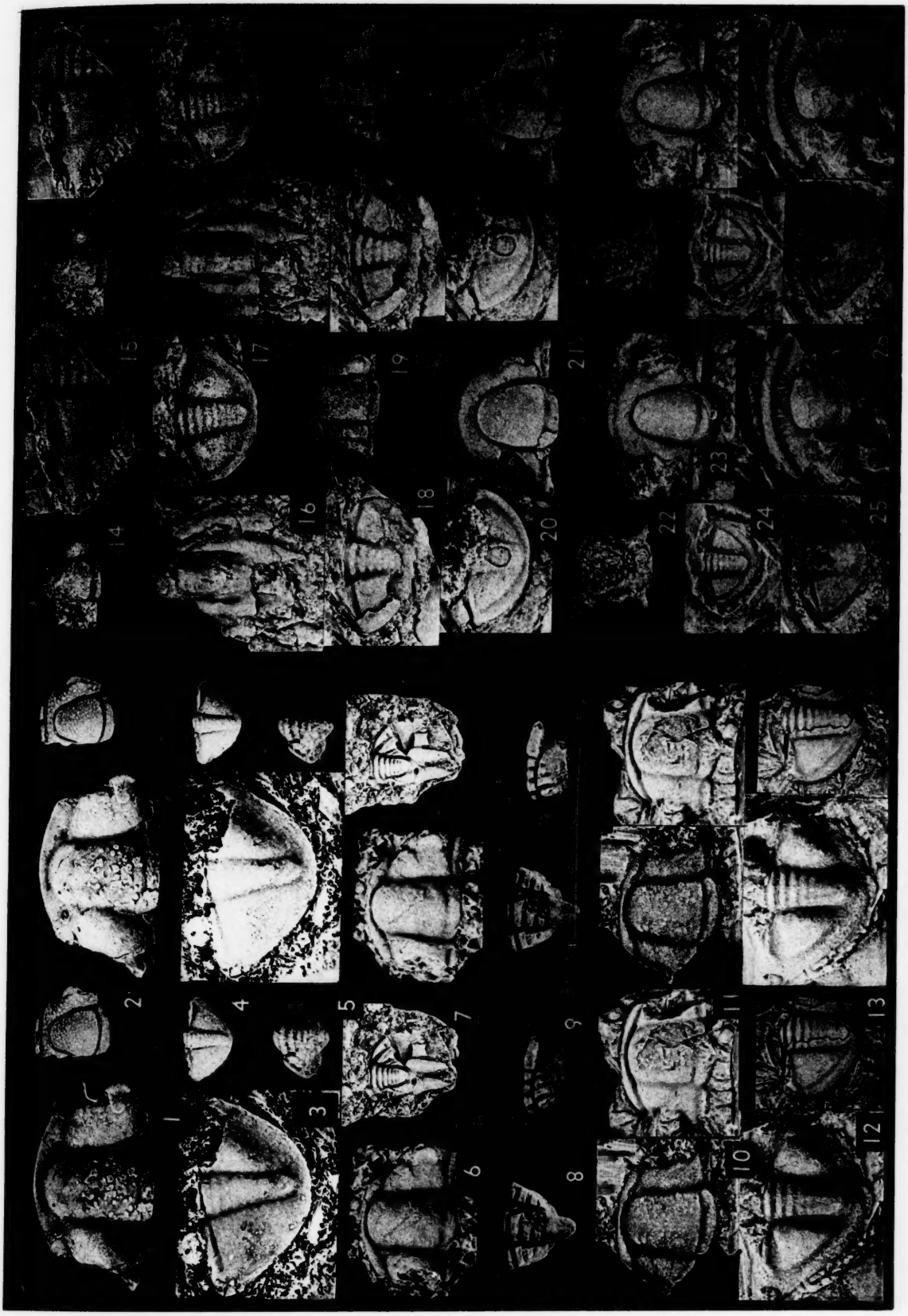
16—Undetermined pygidium No. 2, ×1. Locality WC-106. USNM 136436.

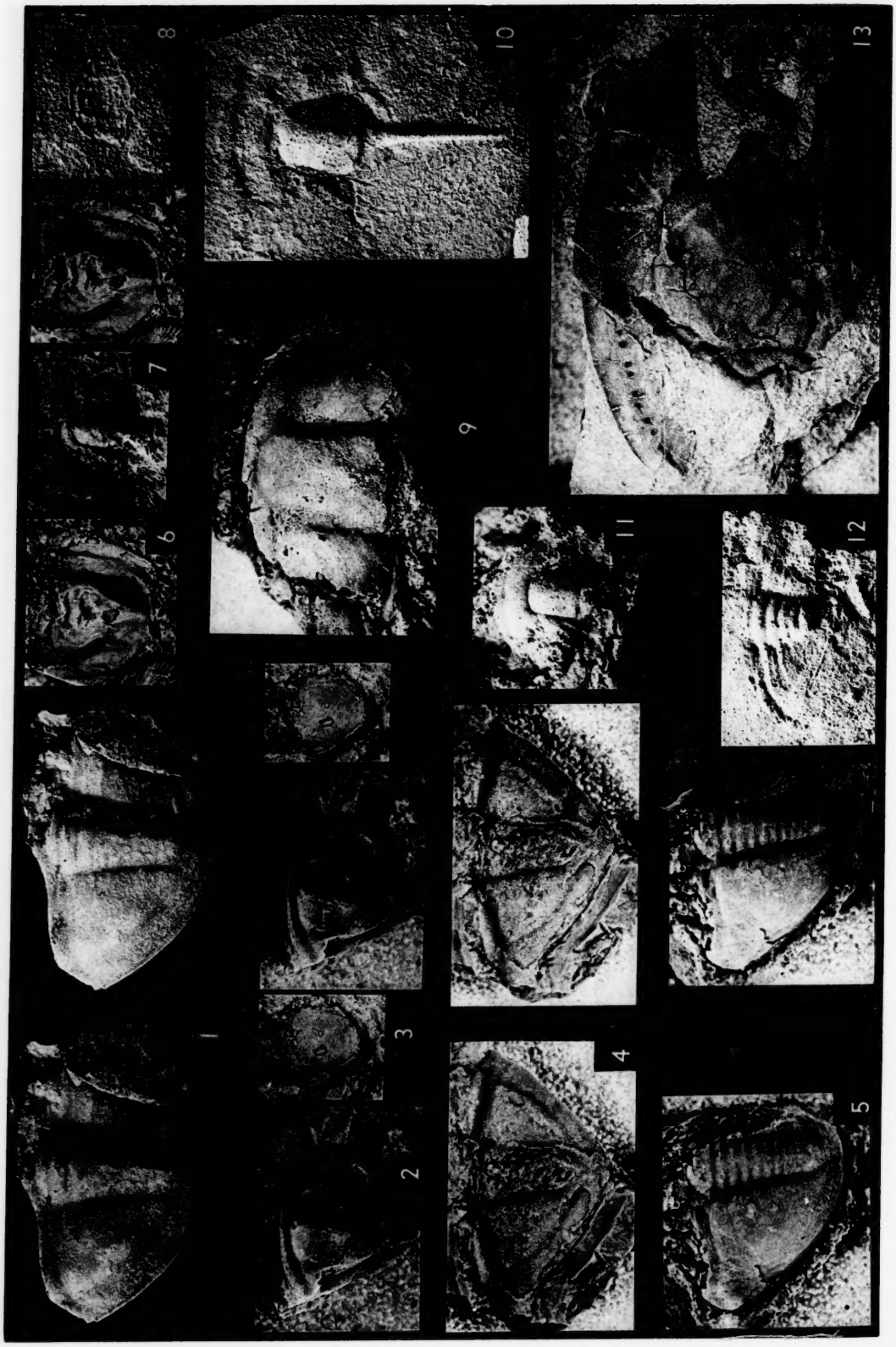
18,20,22—*Bellefontia* sp. cf. *B. chamberlaini* Clark. All from locality MG-112–0. *18*, pygidium, partly decorticated, ×1. USNM 136408. *20*, pygidium, ×1. USNM 136409. *22*, cranidium, poorly preserved, ×1. USNM 136410.

21,23—*Hystricurus?* sp. aff. *H?. genacurvus* (Hintze). Two cranidia, ×2. Locality MG-118-6. Respectively, USNM 136406 and 136407.

25—*Symphysurina* sp. cf. *S. globocapitella* Hintze. Pygidium, ×1. Locality MG-95. USNM 136403.

26—*Kainella* sp. cf. *K. billingsi* Walcott. Cranidium, ×2. Locality D196a €O. USNM 136430.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25


1
2
3
4
5
6
7
8
9
10
11
12
13

Genus KAINELLA Walcott, 1925

KAINELLA sp. cf. K. BILLINGSI Walcott
Pl. 21, fig. 26; pl. 22, fig. 6,13

Kainella billingsi WALCOTT, 1925, p. 102, pl. 22, figs. 1–7.

Specimens are few and poorly preserved. The only pygidium obtained is a fragment from which little can be told other than that it does not belong to *I. flagricauda* (White).

Figured specimens.—USNM 136430, 136431, 136432.

Locality.—D196a €O.

Discussion.—An enormous cranidium is illustrated (pl. 22, fig. 13) without assurance that it belongs with this species. It is one of the largest known for the genus. The exact stratigraphic position within the Manitou formation is not known, nor is the precise locality from which it was collected. The glabella of this specimen is much wider than in *K. billingsi* but the specimen is obviously deformed and cannot by itself be proper grounds for comparison.

Genus GONIOTELOIDES Kobayashi

Gonioteloides KOBAYASHI, 1955, p. 446–447.

Until cephalic parts are identified the relationships of this genus will not be known. In the original description Kobayashi (1955, p. 446) suggested that it might be related to *Goniotelus*, *Goniotelina*, and *Eleutherocentrus*, because of the prolongation of the pygidial axis. Otherwise the similarity to these genera is not particularly striking.

Comparison with *Psalikilus spinosum* (Hintze, 1952, pl. 9, figs. 7a–c) and *Psalikilopsis cuspidicauda* (Ross, 1953, pl. 63, figs. 2,6,7) shows that these share the short, strong segmented portion of the axis, small, almost flat pleural platforms and steep, smooth, "skirt" or border. The rear of each projects backward above the border; although the axis itself is not involved in the resulting overhang, the general construction is similar to that of *Gonioteloides*. This similarity is most striking in *Psalikilus paraspinosum* Hintze, the pygidium of which is illustrated here (pl. 21, fig. 5) for the first time. We therefore suggest that *Gonioteloides* may eventually prove more closely related to *Psalikilus* than to the genera suggested by Kobayashi.

GONIOTELOIDES sp. cf. G. MONOCEROS Kobayashi
Pl. 21, figs. 8,9

Gonioteloides monoceros KOBAYASHI, 1955, p. 447–448, pl. 6, figs. 17a,b, 18a,b; pl. 8, fig. 10.

EXPLANATION OF PLATE 22

(Figures 1–6 are stereo pairs.)

FIGS. *1,2*—*Leiostegium* (*Leiostegium*) sp. Manitou ls. Fish Hatchery, Trout Creek, sec. 21, T. 10 S., R. 69 W. *1*, rubber cast of pygidium, ×1. USNM 136419; *2*, cranidium in fine dolomite, ×1. USNM 136420.

3—*Symphysurina* sp. cf. *S. globocapitella* Hintze. Cranidium, ×1. Locality MG-95. USNM 136404.

4—*Leiostegium* (*Perischodory*) *incompertum*, n. sp. Holotype, pygidium, showing stout stump of lateral spine on left side; right side broken, ×1. Locality 496 R1. USNM 136421.

5,9—*Leiostegium* (*Manitouella*) *ulrichi* n. subgen., n. sp. *5*, paratype, pygidium, large specimen, showing axial rings, ×1. Locality 254 p. USNM 136427. *9*, paratype, cranidium, one of the largest specimens, showing great size of this species, ×1. Locality 254 p. USNM 136423.

6,13—*Kainella* sp. cf. *K. billingsi* Walcott. *6*, pygidium, fragmentary, lacking anterior portion, ×2. Locality D196a €O. USNM 136431; *13*, large cranidium, slightly crushed and with glabella and preglabellar field shortened, ×1. Manitou ls. Locality "Four miles below hotel (site now Experimental Forest HQ), Manitou Park." USNM 136432.

7,11—*Idahoia* sp. Cranidia, ×2. Peerless formation. Locality IG-67. USNM 136400, 136401.

8—*Ellipsocephaloides butleri* Resser. Cranidium, ×1. Peerless formation. Locality IG-68. USNM 136398.

10—*Idahoia wisconsensis* (Owen). Cranidium, ×1. Peerless formation. Locality IG-68. USNM 136399.

12—*Ptychaspis granulosa* (Owen). Pygidium, ×1. Peerless formation. Locality IG-68. USNM 136402.

The single specimen from the Manitou formation is very similar to those described by Kobayashi, although we believe a larger sample might permit separation of a distinct species. The grooved pleural platforms of the Canadian specimens are wider and more broadly curved than those of the Colorado specimen. Otherwise, we are unable to distinguish between them.

Figured specimen.—USNM 136434.

Locality.—Manitou formation, Williams Canyon, Manitou Springs, Colorado. From collection CF-9 of Cloud & Barnes (1948, p. 371). WC-106.

Discussion.—According to Kobayashi (1955, p. 364–366,370–375,448), *G. monoceros* belongs in the "*Symphysurina* fauna" and in the "*Kainella-Evansaspis* fauna"; the first of these he correlates with a similar fauna in Utah and Nevada, zones B-C of Ross (1951, p. 26–32) and of Hintze (1952, p. 5–10). The "*Kainella-Evansaspis* fauna" he correlates with the "E zone" of Ross (1951, p. 26–32) and Hintze (1952, p. 5–10).

The association with *Hystricurus oculilunatus* Ross in the present collection favors a correlation with zone "E" rather than with the lower zone.

Undermined pygidium No. 1
Pl. 21, fig. 7

An indeterminate species is represented by two very fragmentary pygidia. These possess an axis of three rings and a terminus which is marked as if by three incipient intersegmental furrows. There are three pairs of furrowed pleural spines—similar to those of *Apatokephalus* in general shape. The furrows run postero-distally along each spine.

Without better specimens and lacking any cephalic parts, identification of these specimens is almost impossible. Their overall aspect suggests a cheirurid, pliomerid, or similar type. However, the wide ventral doublure covered with Bertillon lines is, as far as we know, not found on such proparian trilobites.

The furrowed pleura are not characteristic of *Kainella*. *Apatokephalus* and its close relatives lack the elongate terminal portion of the axis. Identification must await more complete material.

Figured specimen.—USNM 136435.

Locality.—WC-106 (CF-9 of Cloud & Barnes, 1948).

Undetermined pygidium No. 2
Pl. 21, fig. 16

A single poorly preserved pygidium may belong to the same species as Undetermined pygidium No. 1. However, the pleural spines are furrowed and resemble those of *Apatokephalus*, to which this specimen may belong.

Figured specimen.—USNM 136346.

Locality.—WC-106.

REFERENCES

BEHRE, C. H., 1932, Weston Pass Mining district, Lake and Park Counties, Colorado: Colo. Sci. Soc. Proc., v. 13, p. 57–73.

——, 1953, Geology and ore deposits of the west slope of the Mosquito Range: U. S. Geol. Survey Prof. Paper 235, 176 p., 20 pls.

BELL, W. C., FENIAK, O. W., & KURTZ, V. E., 1952, Trilobites of the Franconia formation, southeast Minnesota: Jour. Paleontology, v. 26, no. 2, p. 175–198, pls. 29–38.

BRAINERD, A. E., BALDWIN, H. L., JR., & KEYTE, I. A., 1933, Pre-Pennsylvanian stratigraphy of Front Range in Colorado: Bull. Am. Assoc. Petroleum Geologists, v. 17, p. 375–396.

BRIDGE, J., & CLOUD, P. E., JR. 1947. New gastropods and trilobites critical in the correlation of Lower Ordovician rocks: Am. Jour. Sci., v. 245, p. 545–559, pls. 1,2.

CLARK, T. H., 1935, A new Ordovician graptolite locality in Utah: Jour. Paleontology, v. 9, no. 3, p. 239–246, pl. 24.

CLOUD, P. E., JR., & BARNES, V. E., 1948, The Ellenburger Group of central Texas: Texas Univ. Bur. Econ. Geol. Pub. 4621, 473 p., 44 pl.

CROSS, C. W., 1894, Description of the Pikes Peak sheet, Colorado: U. S. Geol. Survey, Geologic Atlas, Pikes Peak Folio No. 7, 5 p., maps.

HINTZE, L. F., 1952, Lower Ordovician trilobites from western Utah and eastern Nevada: Utah Geol. and Min. Survey, Bull. 48, 249 p., 28 pls.

JOHNSON, J. H., 1934, Paleozoic formations of the Mosquito Range, Colorado: U. S. Geol. Survey Prof. Paper 185-B, p. 15–43.

KOBAYASHI, T., 1955, The Ordovician fossils from the McKay Group in British Columbia, western Canada, with a note on the Early Ordovician paleogeography: Jour. Fac. Sci. Univ. Tokyo, sec. 2, v. 9, pt. 3, p. 355–493, pls. 1–9.

MAHER, J. C., 1950a, Pre-Pennsylvanian rocks along the Front Range of Colorado: U. S. Geological Survey Oil and Gas Inves. Prelim. Chart 39.

——, 1950b, Detailed sections of Pre-Pennsylvanian rocks along the Front Range of Colo-

rado: U. S. Geol. Survey Circular 68, 20 p., map.

OWEN, D. D., 1852, Report of a geological survey of Wisconsin, Iowa, and Minnesota, and incidentally of a portion of Nebraska Territory, 638 p., Lippincott, Grambo and Co., Phila.

RAYMOND, P. E., 1937, Upper Cambrian and Lower Ordovician trilobita and ostracoda from Vermont: Bull. Geol. Soc. America, v. 48, p. 1079–1146, 4 pls.

RESSER, C. E., 1942, New Upper Cambrian trilobites: Smithsonian Misc. Coll., v. 103, no. 5, p. 1–136, 21 pls.

RICHARDSON, G. B., 1915, Description of the Castle Rock quadrangle, Colorado: U. S. Geol. Survey, Geologic Atlas, Castle Rock Folio, no. 198, 13 p., maps.

ROSS, R. J., JR., 1951, Stratigraphy of the Garden City formation in northeastern Utah and its trilobite faunas: Yale Peabody Mus. Nat. Hist. Bull. 6, 155 p., 36 pls.

——, 1953, Additional Garden City (Early Ordovician) trilobites: Jour. Paleontology, v. 27, p. 633–646, pl. 62–64.

SINGEWALD, Q. D., 1947, Preliminary geologic map and sections of the Upper Blue River Area, Summit County, Colorado: U. S. Geol. Survey.

SWEET, W. C., 1954, Harding and Fremont formations, Colorado: Bull. Am. Assoc. Petroleum Geologists, v. 38, no. 2, p. 284–305.

TWETO, O., 1949, Stratigraphy of the Pando Area, Eagle County, Colorado: Colo. Sci. Soc. Proc., v. 15, p. 149–235.

WALCOTT, C. D., 1925, Cambrian and Ozarkian trilobites: Smithsonian Misc. Coll., v. 75, no. 3, p. 61–146, pls. 15–24.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 120–124, PL. 23, JANUARY 1959

SOME PALEOBOTANICAL PROBLEMATICA

ROLAND W. BROWN
U. S. Geological Survey, Washington, D. C.

ABSTRACT—Problematica encountered by paleobotanists include objects of two kinds: those clearly belonging to the plant kingdom but temporarily unclassifiable, and those whose identity is more doubtful, often raising questions as to whether or not they are of plant, animal, inorganic, or even artificial origin. Two such specimens, one from Eocene and the other from Miocene strata, are discussed here in the hope of receiving helpful suggestions toward their identification. Another, the supposed Eocene cactus, *Eopuntia douglassi* Chaney, from the Green River formation, is here considered to be misidentified for the tuberous rootstock of a sedge, *Cyperus filiferus* (Cockerell) Brown, n. comb.

ABOUT PROBLEMATICA IN GENERAL

NEARLY all paleobotanical papers dealing with extensive floras contain taxonomic sections headed "Plants of unknown affinity," "Incertae sedis," or a phrase of similar import. A suspicion sometimes persists that perhaps even a considerable part of the classified sections should have been assigned to "Incertae sedis." Most of the items in the "unknown" lists are leaves, flowers, fruits, seeds, stems, roots, and wood, readily recognizable as such but apparently, at the moment, impossible to tag with assurance as being related to or belonging to a particular taxon in the plant kingdom. Paleobotanists often feel hopelessly frustrated in the search for clues to acceptable identification. Botanical manuals, herbarium sheets, seed collections, natural history texts, and supposed experts may all prove to be less than adequate. Above all, the fragmentariness of the fossil record is most exasperating. Were a fruit and leaf found attached to a branch; were the venation and marginal dentition of the leaves more clearly preserved; were only a few more of this and that to be had at different localities in the same formation—well, perhaps satisfactory identifications could be made. A problematicum may thus not be recognized at once or for a long time for what it really is and opinions may differ greatly about its assignment when published. Figure 3 represents such a specimen.

Differing from the usual items in the "Incertae sedis" lists are other more puzzling problematica that, although appearing to be plants or parts of plants, may in reality be of animal, inorganic, or even artificial origin. In the course of an active career in the study of fossil plants I have seen many such objects, sometimes mulling over them for many dark years before seeing the light. Often these specimens are merely concretions superficially resembling plants or animals, and the submitter, on being apprised of the fact, is naturally taken aback and disappointed. The "peanuts" sent by a rancher in Texas a few years ago were quite peanutlike in shape and surface markings, but when I received from him the second collection, which I had requested that he make, taking everything at random, it was clear that the first handful had been very carefully selected from among thousands of other odd-shaped, irregular concretions of the same matrix. The identification of most concretionary oddities may yield only additional facts bearing on the origin, distribution, and variety of concretions, but the elucidation of some other long-standing puzzles, as I have illustrated in a number of papers (Brown, 1934–1957), may or may not have petrographic, taxonomic, and stratigraphic significance.

As samples of such unidentified material I take from my office drawers marked "Unsolved mysteries" two of the more attractive specimens (pl. 23, figs. 1,2) and discuss them here. Their features, in contrast with those of many others at which one would hardly be tempted to take a second look, have "character"; that is, once seen they leave an unforgettable impression and can be easily recalled and described, thus enabling ready recognition of similar specimens from other localities. My purpose is twofold. First, I want to emphasize the need for

preserving and publishing problematica because no one can tell when such specimens may provide clues to the solution of other geologic and paleontologic problems. Second, I welcome help in their identification. Should any of my readers have definite suggestions about these objects, and especially references to publications having pertinent descriptions and illustrations, I would appreciate receiving them.

DESCRIPTION OF THE SPECIMENS ON PLATE 23

FIGURE 1. This specimen was collected by me, in company with F. B. Van Houten, on July 19, 1951, from nonmarine, carbonaceous shales in the Aycross formation (middle Eocene), or its lateral equivalent, in SE ¼ NW ¼ sec. 34, T. 32 N., R. 95 W., Fremont Co., Wyoming. The outcrop is on the west side of the road and about ¾ mile north of Wagon Bed spring along the Beaver Divide. Associated with the specimen were many others of the same kind, matted or superimposed on one another through a thickness of 3 cm. of matrix; fish scales; and large two-winged seeds identical with some from the Green River formation (middle Eocene) in Wyoming and Colorado. The strata with these fossils are unconformably overlain by whitish Oligocene rocks containing remains of titanotheres and other mammals.

Noticeable at once in this specimen are the two half-elliptic structures with networks of squarish to hexagonal areas. Around the perimeter the areas are squarish but toward the base they become narrow and diamond-shaped. In the upper structure the basal diamonds surround what purports to be the remains of a stalk, petiole, or peduncle about 1 cm. long. Does this mean that the original was cup-shaped or spathoid? Some dark, carbonaceous debris was found in the hexagonal areas at the time of collection, indicating that the structures are most likely of plant origin. Obscure lines radiating from the centers of the areas in a few specimens may indicate that the areas are apexes of carpels or seeds. These areas are separated from one another by a sharp, narrow ridge along whose crest runs what appears to be a suture line. The ridge, in reverse, as shown by a squeeze, is a furrow, making the areas somewhat craterlike.

From the foregoing facts, is the specimen a fructification of some sort, or some other part of a plant? If a fructification, does it represent the male inflorescence of a cycad; the receptacle of some kind of waterlily; the impression of the fruit of a breadfruit, *Artocarpus;* the fruit of some species in the arum family, Araceae; or is it something that no longer has a living counterpart? A satisfactory answer must take into account the fitness of the plant, if such it be, to have been a component of the large Green River flora, and most explain the mechanics attending the preservation of the original object or its impression as this fossil.

FIGURE 2. This oak leaf was collected by Prof. W. W. Wells, Southern Oregon College of Education, Ashland, Oreg., in 1956, from upper Miocene diatomaceous strata on Little Butte Creek, in sec. 13, T. 37 S., R. 2 E., about 16 miles northeast of Medford, Oregon. It was associated with a variety of other leaves and some seeds.

On the surface of the specimen, magnified twice, may be seen many small boat-shape marks, pointed at one end and blunt-rounded at the other. An overall view shows a rough orientation of these objects with the pointed ends toward the apex of the leaf. Just below the white diagonal band and to the left of the midrib they are arranged in several horizontal rows (pl. 23, fig 4, ×5). A narrow trench bounds each mark, but higher magnification seems to reveal nothing further as a clue to immediate identification. So far as can be seen these marks are confined to the leaf, none appearing on the adjoining matrix.

At first sight the marks look like insect galls. Specialists on galls and gall insects, however, are not convinced that they are galls, because galls of this size should stand more or less upright and, when fossilized, should leave rounded projections or scars. Further, gall insects specialize on particular species of plants. These marks, however, occur not only on oak, as illustrated, but also on alder, maple, sycamore, and others. Some scale insects resemble these marks. If the marks were not acquired when the leaf was still on the tree or on the ground they must have originated after the leaf lay on the bottom of a pool. There the leaf would have been attacked by bacteria, fungi, and

aquatic animals, large and small. Are the marks coprolitic remains? Are they animal tracks? A satisfactory answer to this problem must account for the trench around each mark and for the orientation of the marks.

FIGURE 3. In 1938 I revistited the T. D. A. Cockerell collecting grounds in the Green River formation on the Roan Plateau, northwest of DeBeque, Colorado, and found this compressed elliptic specimen with tufts of fibers at both ends. Casting about for an identification I note that the specimen is remarkably like the segments of the purported cactus, *Eopuntia douglassi* Chaney (1944, p. 507, pls. 1–4) from the Green River formation in northeastern Utah.

The history of the latter illustrates well the differences in interpretation placed upon problematica. For 18 years after its collection by Earl Douglass this object was an unidentified puzzle. However, before and since its publication as a cactus, having handled and drawn the type specimen, I have doubted that it represents a cactus and have maintained that it is rather the flattened, tuberous rootstock of some aquatic or semiaquatic plant despite the fact that the quest for a completely comparable living equivalent has not been successful. The only feature of the specimen that appears to me to be cactuslike is the zigzag arrangement of the segments; but even this is duplicated in the rootstocks of some sedges and other plants. That Dr. Chaney himself had some misgivings about the identification is evident from the numerous qualified statements in his paper, but particularly that on p. 517: ". . . The irregularity in distribution of the areoles on our specimens of *Eopuntia*, the scarcity of spines, the broken end of the flower, and the lack of any sectionable internal structures, leave certain questions unanswered . . ." Let us ponder these unanswered questions with Dr. Chaney's descriptions and illustrations before us.

A decision about the nature of the so-called "areoles" (Chaney, pl. 1b; pl. 2c; pl. 3, fig. 3a; pl. 4, fig. 3a, where they are called branch traces) is fundamental in the solution of this problem. In living opuntias the areoles are complex cushionlike structures, with or without glochidia and spines, and without a definite central pit. Chaney (p. 507) describes the "areoles" as ". . . circular, about 1 mm. in diameter, with a convex scar in the center, closely spaced, and probably spirally distributed. . . ." On p. 515 he says ". . . For comparison, a dried stem joint of the living *Opuntia basilaris* is shown as figure 4 on plate 3; the distribution of the areoles is so similar as to suggest that the areoles of *Eopuntia douglassi* were also spiral in position, though somewhat distorted at the time of burial as a result of drying . . ." If the reader will now inspect Chaney's figures he will find that the "areoles" are, as said, circular in outline, with a conspicuous pit in the center. They may be solitary, but in general they are in sets of 2, 3, or more, linearly, very close together, sometimes almost fused, but neither the solitary ones nor the groups are arranged in any noticeable diagonal or spiral lines as in most opuntias. That they were probably spiral but are now distorted from their original spiral arrangement as a result of drying does not seem to accord with the cited comparison or with normal experience. The areoles of the illustrated *dried* specimen of *Opuntia basilaris* show little or no distortion from a diagonal or spiral arrangement. If the original of the fossil "cactus" was distorted by drying on land, which is perhaps possible, it is highly improbable that the specimen remained so after it lodged in the Green River lake. A dry, wrinkled leaf or fruit (for example, a prune) unwrinkles quickly and assumes its former fresh appearance when thoroughly soaked. Hence I conclude that the irregularity of "areole" arrangement and distribution alone make the Utah specimen suspect of not being an opuntialike cactus.

If the "areoles" are not areoles of a cactus, what are they? As I see them they are root scars exactly like those on the tubers and rootstocks of living grasses and sedges; and on some large monocotyledonous rootstocks I collected from the Wind River formation (Eocene) north of Bonneville, Wyoming, in 1939. The latter are jointed but not zigzagged. Nevertheless, their root scars, some with roots still attached, are arranged irregularly, alone or in multiple sets, just as in Chaney's *Eopuntia*. That the "areoles" of *Eopuntia* are in fact root scars is further indicated by the little remnant in Chaney's pl. 3, fig. 3c of a root, called a leaf (?), still

attached to an "areole"; and of another remnant, called a spine, in his plate 1a. If, as Chaney reiterates throughout his discussion, the surface of the "cactus" was considerably eroded both before and after fossilization, how could a leaf, which is an evanescent structure in most living cacti, survive such rough treatment?

Why is there a "scarcity of spines" on the fossil "cactus"? Most existing opuntias bear abundant, tough, and virtually indestructible spines. Thus, to me it is easier to conceive that *Eopuntia* is not a cactus than that, assuming it to be an opuntialike cactus, it had few, if any, spines in the living state before it was entombed in the sediments. Its identification as the rootstock of a monocotyledon does not strain the imagination and it offers a simple explanation for the absence of spines.

A flower and a fruit are said to be present on the type specimen, Chaney's pl. 2 and pl. 3, fig. 1, respectively, enlarged from pl. 1. These, it appears to me, are neither flower nor fruit but merely segments like the others, as can be seen by a close examination of his plates 1 and 2. In the upper right corner of pl. 2, between the indicator lines of a, is a fairly distinct down-curved line and above the upper indicator line of a is a fainter up-curved line, both curved lines together making a lens-shaped feature, outlining the node or joint of a new segment, only the basal part of which is preserved. In the upper left of the same "flower" between the indicator line b and upper indicator line c, is a similar down-curved line, indicating the node of another segment of which only the basal part is preserved. The fruiting structures of cacti are ultimate and do not produce further segments. Thus, comparison of the "flower" and "fruit" shows that, with their irregularly scattered "areoles" and nodes of new segments, they are just like all the other segments of the fossil. These segments now appear flattened, but the reader must not be deceived into thinking that the original, living organism was necessarily flat, for rootstocks and stems, more or less rounded in the living state may, under proper conditions, leave notably flattened fossil compressions.

As for the "vascular tissue" said to be present in the "cactus," it can be matched readily by similar strands in the rootstocks of living sedges, particularly in *Cyperus rotundus* Linnaeus. Perhaps some of the "vascular tissue" represents a covering of coarse hair or filamentous rootlets.

To the evidence just rehearsed must be added that of two pertinent specimens from Miocene strata at Oeningen along the Rhine River in southern Germany. These were described by Oswald Heer (1859, p. 163, pl. 147, figs. 8,9) as the tuberous rootstocks of a sedge, *Cyperus braunianus*, although he recognized their superficial resemblance to segmented cacti. This evidence was referred to by Chaney (p. 515) but was dismissed as inapplicable to the Utah "cactus" on the assumption that Heer's two specimens do not belong to the same species. Be that as it may, the assumption is beside the point and, in effect, its elaboration obscures or at least minimizes the essential fact, namely, that Heer did indeed have rootstocks with zigzagged segments, in appearance much like the Utah specimen, as can be verified by comparing the several illustrations.

Further specimens derived from other localities in the Green River formation and now seem to be of the same kind as Chaney's *Eopuntia*, were known under other names prior to his paper but were not referred to or recognized as such. For example, Cockerell (1923 p. 4, figs. B,C; 1925, pl. 1, fig. 7) described some filamentous strands as *Diatryma? filifera*, the supposed plumage of the Eocene bird, *Diatryma*. A specimen similar to Cockerell's is in the U. S. National Museum collections and matches the tuft of strands seen in *Carpolithus filiferus* Brown (1934 *b*, p. 67, pl. 15, fig. 18), whose specific term, incidentally, is a coincidence, there having been no intention at that time of synonymy with the Cockerell species. Although true feathers are present in the Green River formation, Cockerell's specimens (except his fig. A, said to be a feather of an unknown bird) are patently not feathers, their relationship being rather with the complex of "vascular strands" associated with the Utah "cactus." *Carpolithus filiferus* was founded on two specimens, both of which show more or less eccentric attachment scars or incipient branches, indicating that they were tuberous segments of a zigzag rootstock. The guess at that writing was that they were a

kind of fruit, perhaps that of some palm. In 1938 I found a number of similar specimens at the same localities northwest of DeBeque, Colorado. One of them is illustrated in figure 3. It is clearly allied to those I previously called *Carpolithus filiferus* and is, moreover, almost an exact duplicate of the more perfect "cactus" segments. Another specimen matches the "cactus flower" (Chaney, pl. 1, upper left segment; pl. 2). Both specimens have "areoles" and "vascular strands" and are without doubt correlative with the segments of the Chaney "cactus."

Associated with the Colorado specimens were species of *Equisetum* and *Lygodium*. The presence of a fragment of an *Equisetum* on the same piece of rock with the "cactus" (Chaney, pl. 4, fig. 1) does not prove that the two species lived close together in the same general environment, but it certainly excites a healthy conjecture that they did. Theoretically, cacti may have been in existence somewhere in Eocene time and perhaps in the Green River flora; but no confirmatory remains, such as pollen, spines, fruits, and seeds, have been found.

My conclusion, therefore, is that *Eopuntia douglassi* is not a cactus. That it is the tuberous rootstock of a sedge seems to be in accord with all the present evidence. Consequently, I rename the species as

CYPERUS FILIFERUS (Cockerell) Brown, n. comb.
Pl. 23, fig. 3

Diatryma? filifera COCKERELL, 1923, p. 1–4, text-figs. B,C [not fig. A, which is a true feather]; 1925, pl. 1, fig. 7.

Carpolithus filiferus BROWN, 1934, p. 67, pl. 15, figs. 17,18.

Eopuntia douglassi CHANEY, 1944, p. 507, pls. 1–4.

REFERENCES

BERRY, E. W., 1937, A correction: Torreya, v. 37, p. 108.

BROWN, ROLAND W., 1934*a*, The supposed fossil ear of maize from Cuzco, Peru: Jour. Washington Acad. Sci., v. 24, p. 293–296.

——, 1934*b*, The recognizable species of the Green River flora: U. S. Geol. Survey Prof. Paper 185, p. 43–77.

——, 1934*c*, *Celliforma spirifer*, the fossil larval chambers of mining bees: Jour. Washington Acad. Sci., v. 24, p. 532–539.

——, 1935, Further notes on fossil larval chambers of mining bees: *Ibid.*, v. 25, p. 526–528.

——, 1938, Two fossils misidentified as shelf-fungi: *Ibid.*, v. 28, p. 130–131.

——, 1939, Some American fossil plants belonging to the Isoetales: *Ibid.*, v. 29, p. 261–269.

——, 1941, The comb of a wasp nest from the Upper Cretaceous of Utah: Am. Jour. Sci., v. 239, p. 54–56.

——, 1946, Fossil egg capsules of chimaeroid fishes: Jour. Paleontology, v. 20, p. 261–266.

——, 1949, Algal pillars miscalled geyser cones: Smithsonian Inst. Ann. Rept. for 1948, p. 277–282.

——, 1950, Cretaceous fish egg capsule from Kansas: Jour. Paleontology, v. 24, p. 594–600.

——, 1957, Plantlike features in thunder-eggs and geodes: Smithsonian Inst. Ann. Rept. for 1956, p. 329–339.

CHANEY, RALPH W., 1944, A fossil cactus from the Eocene of Utah: Am. Jour. Bot., v. 31, p. 507–528.

COCKERELL, T. D. A., 1923, The supposed plumage of the Eocene bird *Diatryma:* Am. Mus. Novitates, no. 62, p. 1–4.

——, 1925, Plant and insect fossils from the Green River Eocene of Colorado: U. S. Nat. Mus. Proc., v. 66, art. 19, p. 1–13.

HEER, OSWALD, 1859, Flora tertiaria Helvetiae, v. 3, p. 1–378.

MANUSCRIPT RECEIVED MARCH 25, 1958.

EXPLANATION OF PLATE 23

All figured specimens are in the U. S. National Museum

FIG. *1*—Unidentified middle Eocene specimen from ¾ mile north of Wagon Bed spring along the Beaver Divide, Wyo. Natural size.

2,4—Unidentified marks on an upper Miocene oak leaf from 16 miles northeast of Medford, Oreg. *2*, ×2. *4*, middle of specimen shown in figure 2, ×5.

3—A segment of *Cyperus filiferus* (Cockerell) Brown, n. comb., from the middle Eocene on the Roan Plateau, 30 miles northwest of DeBeque, Colo. At the upper right and lower left are tufts of fibers at whose bases faint suture lines can be seen. A little to the right of the bottom center is a roundish mark that appears to be the scar where another segment, branch, or stem, was attached. Natural size.

1

2

3

4

1
2
4
3
6
7
14
5
8
10
11
9
17
15
12
13
16

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 125–129, PL. 24, JANUARY 1959

A BAT AND SOME PLANTS FROM THE UPPER OLIGOCENE OF OREGON[1]

ROLAND W. BROWN
U. S. Geological Survey, Washington, D. C.

ABSTRACT—Remains of a bat, not further identified, in strata at Fossil, are here added to the sparse vertebrate fauna reported from the lower (upper Oligocene) part of the John Day formation of north central Oregon. These and correlative beds, however, have yielded a notable flora, listed here by genera as a composite. Some of its constituents, because of their nomenclatural, stratigraphic, and floral significance, receive special comment.

VERTEBRATES FROM THE UPPER OLIGOCENE

EXCEPT bones and scales of fishes few remains of other vertebrates have been reported from the lower (upper Oligocene) part of the John Day formation of north central Oregon. Merriam (1901, p. 294) and Merriam & Sinclair (1907, p. 188) list an entelodont (*Elotherium*), fragments of rhinoceros teeth, and an oreodont (merycoidodont ?) skull found by L. S. Davis but now apparently lost. Chaney (1948, p. 25) states that he found a leg-bone of a quail. In a master's thesis, R. G. Coleman (1949) reported another jaw of an entelodont.

On August 10, 1956, during the collecting of plants from the outcrop of shale behind the schoolhouse at Fossil, I found the jaw and shoulder bones of a bat, here figured (pl. 24, figs. 1–3). For identification of these remains I am indebted to C. Lewis Gazin and David H. Johnson of the U. S. National Museum. Description can add little to the illustrations and better material is needed before the bat can be classified with assurance and extensive comment made about its significance to the time and environment.

[1] Publication authorized by the Director, U. S. Geological Survey.

PLANTS FROM THE UPPER OLIGOCENE

These nonmarine strata, however, are noted for the large, well-preserved flora they have yielded. Special localities where the plants are particularly fine and abundant have for convenience in reference had their names applied to the floral collections, as "The Bridge Creek flora," "The Crooked River flora," "Fossil flora," "Knox ranch flora," "Twickenham ranch flora," "Kennedy ranch flora," etc. These localities lie east of the Cascades, but strata, containing essentially the same flora and correlative at least in age with the lower part of the John Day formation, are now known to be present on the west side of the range in Oregon and Washington.

A striking and readily identifiable item common to all these floras is comprised in the foliage, cones, seeds, and wood of a

EXPLANATION OF PLATE 24

All figures are natural size except as noted and all specimens are in the U. S. National Museum.

FIGS. *1–3*—A bat. *1,2*, counterparts of left ramus of mandible (lower jaw), showing a canine and one incisor (barely visible), ×10; *3*, shoulder bones, humerus above, scapula below, ×5. U.S.G.S. loc. 9420.
4—*Holmskioldia speiri* (Lesquereux) MacGinitie [*Porana speiri* Lesquereux]. U.S.G.S. loc. 9262.
5—*Pinus* sp. U.S.G.S. loc. 9086.
6,7—*Koelreuteria oregonensis* Arnold. U.S.G.S. loc. 9440.
8,9—*Engelhardtia* sp. U.S.G.S. locs. 9086, 9423.
10,11—*Metasequoia occidentalis* (Newberry) Chaney. U.S.G.S. loc. 8641.
12—*Dipteronia insignis* (Lesquereux) Brown. U.S.G.S. loc. 8641.
13—*Hydrangea* sp. U.S.G.S. loc. 9434.
14–16—*Terminalia* sp. U.S.G.S. locs. 9351, 9086, 9420.
17—Seed of *Vitis* sp. ×2. U.S.G.S. loc. 8778.

shuihsa-tree (pl. 24, figs. 10,11), a species of *Metasequoia*, with one living counterpart, *M. glyptostroboides* Hu & Cheng, discovered in Hupeh and Szechuan provinces, western China, in 1944. Originally, the fossil form in Oregon was identified as *Sequoia langsdorfi* Heer and was hailed as the immediate ancestor of the living California coast-redwood, *Sequoia sempervirens* Endlicher (Chaney, 1924; 1925). In consequence, some of the other plants collected with it were identified in terms of species now associated with the coast-redwood. Thus, many of these, in part as a result of the discovery that this "*Sequoia langsdorfi*" is in reality a shuihsa, are known to be misidentified; and beginnings at correcting the errors and their ecologic implications have been made (Brown, 1935–1946; Arnold, 1952; Chaney, 1951; 1952). A list of the modern associates of shuihsa in China (Chu & Cooper, 1950, tables 2 and 3) is revealing and may prove to be very helpful in suggesting comparable living couterparts for many of the misidentified and unidentified floral items in the Oligocene strata of the western United States.

In my opinion the publicity attending the discovery of living shuihsa in China gave the tree a common name that is distinctly an unfortunate misnomer. It was, and in some quarters still is, called the "dawn redwood." Because it is neither a redwood (*Sequoia*), nor a bald cypress (*Taxodium*), but belongs to a distinct genus (*Metasequoia*); and because it was not, so far as now understood, ancestral to redwood or bald cypress, it should not be called "dawn redwood." The name shuihsa (pronounced shweesa), taken from the name of the valley where it occurs, is both euphonious and appropriate. It retains oriental connotations like such others as ailanthus, ginkgo, ginseng, katsura, litchi, loquat, and tea. This, however, is not to say that representatives of redwood and bald cypress are absent from the Oligocene plant record of Oregon. Quite the contrary, species of both occur together or apart at a number of localities.

The distinctive feature of *Metasequoia* is its "oppositeness," the branches, needles, staminate florets, and cone scales being distichous, that is, opposite one another in two rows. Thus, shuihsa can be distinguished easily from redwood and bald cypress, whose needles and other parts are alternate with one another. Only two other coniferous genera, so far as I am aware, have oppositeness, namely, *Amentotaxus* and *Cephalotaxus*, of eastern Asia and Japan. The latter is represented by fossils in the lower Miocene at Eagle Creek, Molalla, and Dexter, Oregon, and in the upper Miocene at Ohop Lake, Washington. In general the needles of *Amentotaxus* and *Cephalotaxus* are larger and coarser than those of *Metasequoia*. Figure 9, a cone, and Figure 10, a twig, of *Metasequoia occidentalis* (Newberry) Chaney, are from U.S.G.S. loc. 8641, on Bridge Creek, 9 miles west of Mitchell, Oreg.

At U.S.G.S. loc. 9086, a former road metal quarry at the junction of the highways one-fourth mile north of Goshen, the dark gray shales contain a large flora with species of the following genera: *Abies, Cunninghamia, Libocedrus* [? *Fokienia*], *Pinus* (2 spp.), *Sequoia, Alnus, Engelhardtia, Carya, Quercus, Platanus, Cercidiphyllum, Cinnamomum, Sassafras, Crataegus, Cercis, Mahonia, Exbucklandia, Hydrangea, Acer, Arbutus, Holmskioldia* [*Porana*]. In composition this flora matches that from Rujada, east of Cottage Grove. As many of the same species of these floras also occur in the Bridge Creek flora east of the Cascades there is a strong presumption of correspondence in age. Among the notable specimens is a large pine seed (pl. 24, fig. 5). Pine foliage is represented by 3-needled and 5-needled clusters, thus indicating that at least two species of *Pinus* were present in that forest. To which of these, if any, the large seed belongs is perhaps not determinable. Both yellow pine (*P. ponderosa* Lawson) and sugar pine (*P. lambertiana* Douglas) produce seeds somewhat comparable to the fossil in size and shape. My guess is that the seed belongs to a sugar pine of the 5-needled group.

Also at U.S.G.S. loc. 9086 occur the leaves and fruits (pl. 24, fig. 8) of an *Engelhardtia*, a genus of the walnut family (Juglandaceae). The larger fruits are scarcely distinguishable from those called *E. nevadensis* MacGinitie, from the Eocene at You Bet, California, and others found by the writer in the Clarno formation (Eocene) on West Branch, 4 miles southwest of Mitchell, Oregon. The smaller fruits are like those called

E. olsoni Brown, from the Miocene on Orofino Creek, Idaho. Both the large and small fruits are matched by those erroneously assigned to *Carpinus grandis* Unger by Chaney (1927, p. 105, pl. 9, figs. 7–9), from the Bridge Creek and Crooked River floras in central Oregon. Distinction of species here may be possible by comparison of the associated foliage when such becomes available at the several other localities cited. At U.S.G.S. loc. 9423, on Willow Creek, east of Ager and 10 miles north of Montague, California, is an outcrop of shale containing species of the following genera: *Ginkgo*, *Thuja* (or *Chamaecyparis*), *Cunninghamia*, *Taxodium*, *Quercus*, *Engelhardtia*, *Ulmus*, *Cercidiphyllum*, *Platanus*, *Cercis*, *Cornus*, and *Holmskioldia*. This is ostensibly an upper Oligocene flora, and, as will be noted, contains an *Engelhardtia* fruit (pl. 24, fig. 9) similar to that from loc. 9086; and a *Holmskioldia*, unfigured, but like that shown on pl. 24, fig. 4.

The sterile, usually 4-parted, apetalous flowers of hydrangea of the saxifrage family (Saxifragaceae) turn brown and tough on ripening and thus become good prospects for preservation as fossils when other conditions are favorable. Such flowers (calyces) have been reported from the Eocene of Alaska and Chalk Bluffs, California; the Oligocene at Florissant, Colorado; and the Miocene at Spokane, Washington, and at Van Horn ranch, John Day Valley, Oregon. The large specimen figured here (pl. 24, fig. 13) lacks one of its original 4 sepals. It is from a small upper Oligocene collection made at U.S.G.S. loc. 9434, near the former village of Landax, on the north side of Lookout Point dam on the middle fork of the Willamette River, southeast of Eugene, Oregon. The collection contains, in addition, species of *Pinus*, *Sequoia*, *Carya*, *Engelhardtia*, *Quercus*, and *Platanus*. Pending the finding of leaves that may help to distinguish it from other named species, I refrain from naming this hydrangea specifically.

In 1940 I described a leaf of *Dipteronia insignis* (Lesquereux) Brown (p. 351, fig. 17) taken from the shales on Bridge Creek, U.S.G.S. loc. 8641, and added: "The rounded, winged fruits have not yet been reported from the same locality, but they may be looked for with confidence." On December 9, 1957, I received from my former assistant, Jack Wolfe, the specimen figured here (pl. 24, fig. 12), a satisfactory fulfillment of my prediction. The right-hand side of the specimen, it should be noted, is a straight scar, denoting where its twin, as in maples, was attached. The only authentic dipteronias so far known in the fossil record of the United States are from Oligocene strata, *D. americana* Brown from Republic, Washington and *D. insignis* (Lesquereux) Brown from Florissant, Colorado, and Bridge Creek, Oregon. The differences between these species, if any, are slight. *Dipteronia*, a genus the maple family (Aceraceae), is exemplified today by two species, *D. sinensis* Oliver and *D. dyerana* Henry, in central and southwestern China, but it is not listed by Chu and Cooper as an associate of shuihsa in Hupeh and Szechuan provinces.

Several undoubted species of *Koelreuteria*, a genus of the soapberry family (Sapindaceae) have been identified in the fossil record of the western United States since Edwards detected the first, *K. alleni* (Lesquereux) Edwards, from the Oligocene shales at Florissant. One species, *K. annosa* Brown, is from Paleocene strata northeast of Point of Rocks, Wyoming; *K. mixta* (Lesquereux) Brown is from the Eocene at Chalk Bluffs, California; *K. nigricans* (Lesquereux) Brown is from the Green River formation (Eocene) at localities in Colorado and Wyoming; and *K. oregonensis* Arnold (1952, p. 77, pl. 1, figs. 1–3) is from the upper Oligocene at Knox ranch, U.S.G.S. loc. 9440, southwest of Fossil, Oregon. None has been found in younger rocks. The two specimens (pl. 24, figs. 6,7) of *K. oregonensis* are from the Knox ranch locality. This genus, with 4 species, is now confined to eastern Asia. The Chinese name for these trees is luanshu.

One of the most prolific localities in the lower part of the John Day formation has been U.S.G.S. loc. 8778, the Gray or McCullough ranch on Crooked River, 11 miles east of Post. Most of the specimens illustrated in Chaney's 1927 paper came from this locality, but apparently nothing definitely attributable to the grape family (Vitaceae) was found. As grapevines commonly grow near streams where the leaves and fruits can fall readily into water and be carried to a suitable burial site, it seems

strange that no such foliage has yet been reported from these strata. However, in 1941 I found the unmistakable seed shown here (pl. 24, fig. 17). Appropriate leaves may, therefore, be expected.

The 3 elliptic fruits (pl. 24, figs. 14–16) come from different upper Oligocene localities in Oregon: figure 14, U.S.G.S. loc. 9351, on the right bank of Thomas Creek, 8 miles east of Jordan; figure 15, loc. 9086, one-fourth mile north of Goshen; and figure 16, loc. 9420, behind the schoolhouse at Fossil. The smallest specimen (fig. 15) is almost an exact duplicate of *Terminalia estamina* MacGinite (1941, p. 152, pl., 43, fig. 4) from the Eocene at Chalk Bluffs, California. The other specimens are somewhat larger. Although these specimens look superficially like the fruits of *Halesia* and *Bulnesia*, they are most like those of *Terminalia*, particularly *T. paniculata* Roth from the western part of India. If this identification is correct, we have here an apparent subtropical relict held over from the late Eocene into Oligocene floras. *Terminalia* is a genus of the Combretaceae, which is distributed widely in the tropics and subtropics of both hemispheres.

The morning glorylike flower (pl. 34, fig. 4) is perhaps a calyx rather than a corolla. It comes from U.S.G.S. loc. 9262, at Shale City in the foothills of Grizzly Peak, east of Ashland. Associated with it are species of *Abies, Libocedrus, Metasequoia, Pinus, Quercus, Alnus, Betula,* and *Acer*. Specimens similar to this occur in the Eocene in the Green River formation of Wyoming, and in the Clarno formation on West Branch, Oregon; in the Oligocene at Florissant, Colorado; at Republic, Washington, where it was misidentified by Berry as *Hydrangea bendirei* (Ward) Knowlton; at the localities in the lower part of the John Day formation of Gray ranch on Crooked River, Taylor ranch on Bridge Creek, Knox ranch, Fossil, and Cove Creek; and at the Goshen flora locality, 1½ miles south of Goshen, Oregon, where it was misidentified as *Viburnum palmatum* Chaney and Sanborn. Nowhere in the western United States has this flower been found in strata definitely known to be younger than Oligocene. It, and its compositional associates, therefore, are valuable guides, regionally, to determination of age. These flowers were originally called *Porana speiri* Lesquereux, a species in the morningglory family (Convolvulaceae), but in 1953 MacGinitie (p. 156, pl. 74, figs. 1, 2) referred them to *Holmskioldia*, a genus of the Verbenaceae. If this identification holds, we have here another tropical or subtropical holdover into Oligocene floras.

Taking all known more or less correlative upper Oligocene localities and their floras into consideration, a composite flora along the Cascade Range and adjacent areas includes species of the following genera. Some of these are questioned because the identifications are still regarded as somewhat doubtful:

Ferns: *Dryopteris?, Hemitelia, Pteris?*

Gymnosperms: *Ginkgo, Abies, Callitris, Chamaecyparis, Cunninghamia, Libocedrus [?Fokienia], Metasequoia, Pinus, Pseudotsuga?, Sequoia, Taxodium, Thuja, Torreya?*

Angiosperms: (Monocots) *Cyperacites, Potamogeton, Sparganium, Typha.* (Dicots) Salicaceae—*Salix?, Populus?;* Juglandaceae—*Carya?, Engelhardtia, Juglans?, Pterocarya;* Betulaceae—*Alnus, Betula, Carpinus, Ostrya;* Fagaceae—*Castanea, Fagus, Quercus;* Ulmaceae—*Celtis* or *Pteroceltis, Ulmus, Zelkova;* Proteaceae—*Banksites;* Nymphaeaceae—*Nymphaea;* Cercidiphyllaceae—*Cercidiphyllum;* Berberidaceae—*Mahonia;* Lauraceae—*Cinnamomum, Sassafras;* Hamamelidaceae—*Exbucklandia, Liquidambar;* Platanaceae—*Platanus;* Saxifragaceae—*Hydrangea, Philadelphus;* Rosaceae—*Amelanchier, Crataegus, Prunus, Rosa;* Leguminosae—*Cercis, Cladrastis, Micropodium;* Meliaceae—*Cedrela;* Anacardiaceae—*Rhus?; Aceraceae—Acer, Dipteronia;* Sapindaceae—*Koelreuteria;* Rhamnaceae—*Ceanothus, Paliurus?;* Vitaceae—*Vitis;* Tiliaceae—*Tilia;* Dilleniaceae—*Dillenites?;* Combretaceae—*Terminalia;* Cornaceae—*Cornus;* Ericaceae—*Arbutus, Rhododendron;* Styracaceae—*Halesia?;* Gentianaceae—*Nymphoides;* Verbenaceae—*Holmskioldia [Porana].*

An inspection of this list reveals an overwhelming proportion of plants adapted to a moderate temperate climate with adequate precipitation to support a mesophytic forest cover. Many of these have Asiatic relatives, and some have affinities with species in the Mexican uplands; but a few seem to be most closely allied to species now living in the

warm subtropics. The latter remained from the warmer lower Oligocene and Eocene floras that once existed in the same region.

It should be noted that the upper Oligocene flora does not contain the fern called *Lastrea fischeri* Heer. This species, so far as now known, did not survive the early Oligocene in western America and hence purports to be a reliable dating index for the late Eocene and, perhaps rarely, early Oligocene in the Cascade region. The upper Eocene and lower Oligocene floras contain a high percentage of species with tropical or subtropical affinities, but the upper Oligocene flora is notably temperate, showing a strong trend toward cooler conditions. One form that apparently did not survive the upper Oligocene is *Holmskioldia* [*Porana*]. This, therefore, as stated before, seems to be a good dating index for separating the upper Oligocene from the lower Miocene.

The trend toward cooler but still mesophytic conditions continued well into or through the Miocene. One after another the subtropical floral relicts from the upper Oligocene dropped out and species developed that were adapted in part to climatic conditions somewhat similar to those now prevailing west of the Cascades, or more specifically, to those in eastern United States, eastern Mexico, and eastern Asia.

Finally, I would like to call attention to an absentee in the upper Oligocene floras of the Cascade region—*Ailanthus*, the tree of heaven. Species of *Ailanthus* have been recorded from the Eocene of Montana, Wyoming and central Oregon, the Oligocene at Florissant, Colorado, and Ruby Valley, Montana, and the Miocene of eastern and southeastern Oregon. It would seem that *Ailanthus* should have been at home in the Cascade region during the Oligocene. Was it actually there, and if so, why is it missing from the plant collections?

REFERENCES

ARNOLD, C. A., 1952, Tertiary plants from North America: The Paleobotanist, v. 1, p. 73–78.

BROWN, R. W., 1935, Miocene leaves, fruits and seeds, from Idaho, Oregon, and Washington: Jour. Paleontology, v. 9, p. 572–587.

——, 1937*a*, Additions to some fossil floras of the western United States: U. S. Geol. Survey Prof. Paper 186, p. 163–206.

——, 1937*b*, Fossil legumes from Bridge Creek, Oregon: Jour. Washington Acad. Sci., v. 27. p. 414–418.

——, 1937*c*, Further additions to some fossil floras of the western United States: Jour. Washington Acad. Sci., v. 27, 506–517.

——, 1940, New species and changes of name in some American fossil floras: Jour. Washington Acad. Sci., v. 30, p. 344–356.

——, 1946, Alterations in some fossil and living floras: Jour. Washington Acad. Sci., v. 36, p. 344–355.

——, 1950, An Oligocene evergreen cherry from Oregon: Jour. Washington Acad. Sci., v. 40, p. 321–324.

CHANEY, R. W., 1924, Quantitative studies of the Bridge Creek flora: Am. Jour. Sci., v. 8, p. 127–144.

——, 1925, A comparative study of the Bridge Creek flora and the modern redwood forest: Carnegie Inst. Washington Pub. 349, p. 1–22.

——, 1927, Geology and paleontology of the Crooked River basin, with special reference to the Bridge Creek flora: Carnegie Inst. Washington Pub. 346, p. 47–140.

——, 1948, The ancient forests of Oregon: Condon lectures, p. 1–56. Oregon State System of Education, Eugene, Oreg.

——, 1951, A revision of fossil Sequoia and Taxodium in western North America based on the recent discovery of Metasequoia: Am. Philosoph. Soc., v. 40, p. 169–263.

——, 1952, Conifer dominants in the Middle Tertiary of the John Day Basin, Oregon: The Paleobotanist, v. 1, p. 105–113.

CHU, KWEI-LING, & COOPER, W. S., 1950, An ecological reconnaissance in the native home of Metasequoia glyptostroboides: Ecology, v. 31, p. 260–278.

COLEMAN, R. G., 1949, The John Day formation in the Picture Gorge Quadrangle, Oregon: Oregon State College Master's Thesis.

MACGINITIE, HARRY G., 1941, A Middle Eocene flora from the central Sierra Nevada: Carnegie Inst. Washington Pub. 534, p. 1–178.

——, 1953, Fossil plants of the Florissant beds, Colorado: Carnegie Inst. Washington Pub. 599, p. 1–198.

MERRIAM, J. C., 1901, A contribution to the geology of the John Day Basin: Bull. Dept. Geol. Univ. Calif., v. 2, no. 9, p. 269–314.

——, & SINCLAIR, W. J., 1907, Tertiary faunas of the John Day region: Bull. Dept. Geol. Univ. Calif., v. 5, no. 11, p. 171–205.

MANUSCRIPT RECEIVED OCTOBER 3, 1958

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1. P. 130–137, PLS. 25,26, 6 TEXT-FIGS., JANUARY 1959

LOWER MISSISSIPPIAN HOLOTHURIAN SCLERITES FROM THE ROCKFORD LIMESTONE OF NORTHERN INDIANA

RAYMOND C. GUTSCHICK
University of Notre Dame, Notre Dame, Indiana

ABSTRACT—Study of more than five hundred holothurian sclerites from water washed shales in the Lower Mississippian Rockford limestone formation of Jasper County, Indiana, reveals four genera and ten species of which the following four species are new: *Thuroholia spicatus*, *Achistrum brevis*, *Microantyx botoni*, and *Rota campbelli*. The fauna bears resemblance to holothurian remains from the Lower Mississippian Escabrosa limestone of southern Arizona and the Lower Carboniferous of Scotland.

INTRODUCTION

THE Lower Mississippian Rockford limestone has a very limited outcrop indeed in northern Indiana. It is at one of these restricted placed that an important microfauna has been discovered which includes abundant fairly diverse holothurian wheels, sieve plates, and hook sclerites. The locality is a small, shallow, abandoned quarry in Mr. Chris E. Alter's farmyard along the head of Meadel Ditch (county highway map) near the center of the NW¼ of Section 21, T. 27 N., R. 7 W., Jasper County, Indiana, which is about 3½ miles WNW of Remington. The small outcrop that remains is along this ditch. Gutschick & Treckman (1957*a*) described a small collection of cephalopods from the Rockford beds at this locality and give the details of stratigraphy. The beds also contain a diverse arenaceous foraminifera fauna (Gutschick & Treckman, 1957*b*). The holothurian fauna was obtained from water washings of shales which occur as partings up to a few inches thick between thin limestone layers in the upper part of the Rockford limestone unit.

The fauna consists of the following four genera and ten species of which five species are new. This would include one form which probably belongs to a new genus and new species although material was not entirely satisfactory for establishing its taxonomic position. The wheel sclerites are far more abundant than either hooks or sieve plates.

Thuroholia marginata Langenheim & Epis, 1957
T. mccormacki (Frizzell & Exline), 1955
T. spicatus, n. sp.
Achistrum brevis, n. sp.
A. ludwigi (Croneis) Deflandre-Riguad, 1952
A. nicholsoni Etheridge, 1881
A. triassicum? Frizzell & Exline, 1955
Rota campbelli, n. sp.
Microantyx botoni, n. sp.
New genus?, new species

Preservation is generally quite good although many of the forms are very fragile and occur as fragments. The fossils are composed of white, semi-transparent calcite in a yellowish-orange (10YR 7/6) ganular matrix which often adheres to them. The rock in which they are found is a soft, calcareous, fossiliferous shale. The associated microfauna includes arenaceous foraminifera, conodonts, nepionic brachiopods, ostracodes, microcrinoids, calcareous worm tubes, dissociated echinoderm plates, gastropods, and fish teeth. The megafauna which is sparse due to the limited exposure contains nautiloid and goniatite cephalopods, brachiopods, small solitary corals, and crinoid fragments.

The recent monographic study by Frizzell & Exline (1955) has been indispensable in working out the taxonomy of the fauna. Relatively little is known about Paleozoic holothurian faunas and less about early Mississippian forms. Pertinent references would include the study of Martin, 1952, on Devonian forms from Iowa; Langenheim & Epis, 1957, Lower Mississippian Escabrosa limestone of Arizona; Etheridge, 1881, Lower Carboniferous of Scotland; and Croneis & McCormack, 1932, on late Mississippian Chester forms from Illinois. The latter paper also discusses younger Paleozoic faunas.

The entire aspect of this unique fauna is significant since it differs markedly from the described Devonian material and also

from the later Chester faunas; yet it bears some remarkable similarity to the limited Escabrosa limestone material of Langenheim & Epis and the Scottish Lower Carboniferous of Etheridge. Both *Thuroholia marginata* and *Rota campbelli*, n. sp., are common to the Escabrosa and Rockford limestones. The types of *Achistrum frizzelli* Langenheim & Epis leave much to be desired for comparison and it is possible that some of the Rockford material may be conspecific with this form. *Rota martini* (restricted) is not recognized in the Rockford samples. *Thuroholia mccormacki* and *Achistrum nicholsoni* from the Rockford agree reasonably well with Etheridge's type descriptions and there is some similarity of representatives of the Rockford Theeliidae with those from the Lower Carboniferous of Scotland. Frizzell & Exline (1955, p. 141) recognize a specimen in the collection of John W. Koenig of the Missouri Geological Survey as *Paleochiridota plummerae* Croneis. The specimen was collected from the Lower Mississippian Kinderhook McCraney limestone of Illinois, which is very likely correlative of the Rockford limestone of Indiana (Workman & Gillette, 1956, p. 8, 35). It is possible that the McCraney form is closely related if not identical to *Microantyx botoni* although the former has six perforations as compared to eight for the latter. The Rockford fauna gives encouragement for the usefulness of the holothurians for correlation and points to the desperate need for many more detailed faunal studies to fill the Paleozoic gaps in the phylogeny of the sea cucumbers.

In connection with the stratigraphy Gutschick & Treckman (1957*a*, p. 1149) misinterpreted Campbell's recent abstract (1956, p. 1679), implying that the latter restricted the New Albany shale to the Devonian. This is erroneous for Campbell regards the New Albany shale as both Devonian and Mississippian in age. No holothurian fossils have been described from the Rockford of southern Indiana or rocks associated with the Rockford.

Acknowledgement is expressed to Mr. Chris E. Alter who has kindly given access to the section and friendly help, to Professor R. L. Langenheim, Jr., of the University of California for the slides of paratypes from the Escabrosa limestone of Arizona, and to Mr. William Garvey, student at Notre Dame, for help in collecting, preparing and studying the samples.

SYSTEMATIC DESCRIPTIONS

Phylum ECHINODERMATA
Class HOLOTHUROIDEA
Family CALCLAMNIDAE Frizzell & Exline, 1955
Genus THUROHOLIA Gutschick, 1954

Achistrum ETHERIDGE (in part), 1881, p. 194, pl. 194, pl 5, figs. 1–5.
Thuroholia GUTSCHICK, 1954, p. 827, text figs. 1–19.
Eocaudina MARTIN, 1952, emend. Frizzell & Exline, 1955, p. 82.
Thuroholia LANGENHEIM & EPIS, 1957, p. 167.

The genus is represented by three species in the Rockford limestone, one of which is new; however specimens are not common probably due to their fragility.

THUROHOLIA MCCORMACKI (Frizzell & Exline)
Pl. 25, figs. 1,5

Eocaudina mccormacki FRIZZELL & EXLINE, 1955, p. 87, pl. 3, fig. 9.

As Frizzel & Exline point out, it is extremely difficult to distinguish between *Thuroholia croneisi*, *T. gutschicki*, and *T. mccormacki* from fragmentary material. The Rockford specimens related to these forms are uncommon and broken yet distinctly different from other forms of the genus. Material assigned to this species is based upon the more numerous rows and numbers of perforations along with the tendency of the sclerites to be hexagonal in outline. The plates have a maximum diameter of approximately 0.60 mm.

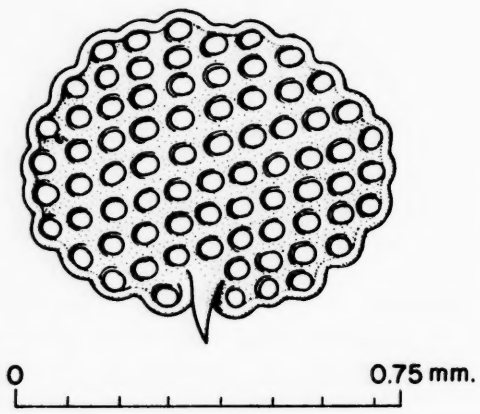
THUROHOLIA MARGINATA Langenheim & Epis
Pl. 25, figs. 2,6

Thuroholia marginata LANGENHEIM & EPIS, 1957, p. 167, pl. 1, figs. 7–16.

Prof. Langenheim furnished me with paratypes of *T. marginata* from the Lower Mississippian Escabrosa limestone of southern Arizona which were used for comparison. Although this form is rare in the Rockford, specimens agree reasonably well with the paratypes.

THUROHOLIA SPICATUS, n. sp.
Pl. 25, figs. 3,4,7–9; text-fig. 1

Description.—Sclerite in form of thin, flat, perforate plate; outline subround to elliptical, undulating; perforations fine to medium, subequal, subcircular to circular, edges bevelled; perforations arranged in more or less parallel, diagonal rows, usually ten rows across sclerite; the margin of sclerite strongly scalloped, the scallops bordering one and often several perforations; the margin gives impression of being raised slightly so as to form a low rim. There is a prominent sharp short spine which projects outwards from the margin of the sclerite at an angle of approximately 30° or less with the plane of the plate. The base of the spine is normally one or two rows of perforations in from the margin. The margin closest to the spine tends to be linear.



TEXT-FIG. 1—Generalized sketch of *Thuroholia spicatus*, n. sp.

Dimensions.—Maximum diameter of holotype 0.75 mm., paratypes 0.49 mm., 0.68 mm., and 0.64 mm.; approximate diameter of perforations 0.02 to 0.03 mm.; number of perforations 88 in holotype; approximate length of spine 0.07 to 0.10 mm. for paratypes.

Remarks.—*Thuroholia spicatus* is similar to *T. croneisi*, *T. gutschicki*, and *T. mccormacki* but can easily be distinguished from these because of the conspicuous development of a spine and a scalloped border. Sclerites in this genus are fragile and generally occur as fragmentary specimens so that it would be difficult to assign these specifically in the absence of the spine and outer margin.

Types.—Holotype: U.S.N.M. 137002; paratypes: U.S.N.M. 137003, 137004, and 137005.

ACHISTRUM NICHOLSONI Etheridge
Pl. 25, figs. 10–12

Achistrum nicholsoni ETHERIDGE (in part), 1881, p. 195, pl. 5, figs. 7a,b.

Single sclerite is in form of a hook which is very large for the genus and species; otherwise its shape fits the description given by Frizzell & Exline (1955, p. 98).

Dimensions.—Length, 1.36 mm.; width, 0.35 mm.; maximum diameter of shaft, 0.18 mm.; thickness of eye, 0.11 mm.; outer diameter of eye, 0.31 mm.; long diameter inside eye, 0.19 mm.; short diameter inside eye, 0.15 mm.

Remarks.—The curvature of the spear does not fit Etheridge's illustrations of the types but comes in between the range of variation. The sclerite resembles *A. frizzelli* Langenheim & Epis from the Escabrosa limestone of southern Arizona except for larger size and the lack of inclination of the eye towards the shaft; however preservation and illustration of the types of *A. frizzelli* leaves much to be desired for close comparison. Difference in size is the only distinction the authors single out in comparing *A. frizzelli* with *A. nicholsoni*.

ACHISTRUM BREVIS, n. sp.
Pl. 25, figs. 20–24; text-fig. 2

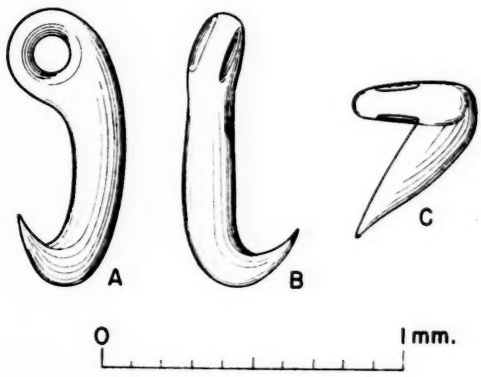
Description.—Sclerite in form of hook; shank short, stout, circular in cross-section, even in diameter throughout, slightly curved and twisted; eye large, oblique to plane of spear and shaft making an angle of about 60° with spear, strongly offset to axis of shank, slightly inclined to plane of shank, perforation simple, circular to oval; short to medium length spear, curved, may be twisted on shaft to right or left fairly sharply pointed but the tip is often broken off.

Dimensions.—Measurements on three specimens are as follows:

	Holotype U.S.N.M. 137013	Paratype U.S.N.M. 137014	Paratype U.S.N.M. 137015
Length	0.91 mm.	0.91 mm.	0.90 mm.
Width	0.48	0.34	0.37
Max. diam. shank	0.16	0.17	0.18
Thickness of eye	0.12	—	—
Outer diam. of eye	0.29	0.27	0.27
Long diam. inside eye	0.16	0.16	0.17
Short diam. inside eye	0.13	0.13	0.13

Remarks.—This species is characterized by its short robust form, eye offset from axis of shank, strongly incurved, sharply acute spear which is twisted oblique to plane of shank and eye. It does not resemble any of the described forms. The collection contains more than ten specimens of this form.

Types.—Holotype: U.S.N.M. 137013; paratypes: U.S.N.M. 137014, 137015, 137016.



TEXT-FIG. 2—Sketch of *Achistrum brevis*, n. sp., based upon holotype, U.S.N.M. 137013. A, front view. B, side view. C, top view, showing angularity between planes of eye and spear.

ACHISTRUM LUDWIGI (Croneis)
Pl. 25, figs. 13–19

There are some twenty or more specimens which have been tentatively identified in the above species although it is not entirely clear whether the type has a circular shaft or not. The Rockford specimens are characterized by sweeping curved shafts which are elliptical in cross-section (see pl. 25, figs. 16,17); otherwise the sclerites agree with the type in having a relatively large eye opening whose rim is moderately inclined towards the spear.

Dimensions.—Measurements of three typical specimens are as follows:

	U.S.N.M. 137012	U.S.N.M. 137008	U.S.N.M. 137007
Length	1.17	0.90+	0.96
Width	0.45	0.36+	0.49
Max. width of shaft	0.15	0.15	0.17
Thickness of shaft	0.08	0.08	0.08
Outside width of eye	0.20	0.20	—
Inside width of eye	0.08	0.08+	—
Inside length of eye	0.12	0.12	—
Width of shaft at eye	0.10	0.11	0.12

ASCHISTRUM TRIASSICUM?
Frizzell & Exline
Pl. 25, figs. 25,26

Three or four fragmentary hooks occur in this fauna which are different than any other Rockford form. The sclerites are long, slender and strongly curved with short spear. They bear closest resemblance to

A. triassicum except for the relationship between the plane of the spear and the eye. In view of the fragmentary nature of the specimens, they are questionably placed in this species. The following measurements are given for the specimen illustrated: Length greater than 1.28 mm., width 0.35 mm., maximum diameter of shaft 0.085 mm., outer diameter of eye 0.16 mm.

Family THEELIIDAE Frizzell & Exline, 1955
Genus MICROANTYX Kornicker & Imbrie
MICROANTYX BOTONI, n. sp.
Pl. 26, figs. 22,23,28,29; text-fig. 3

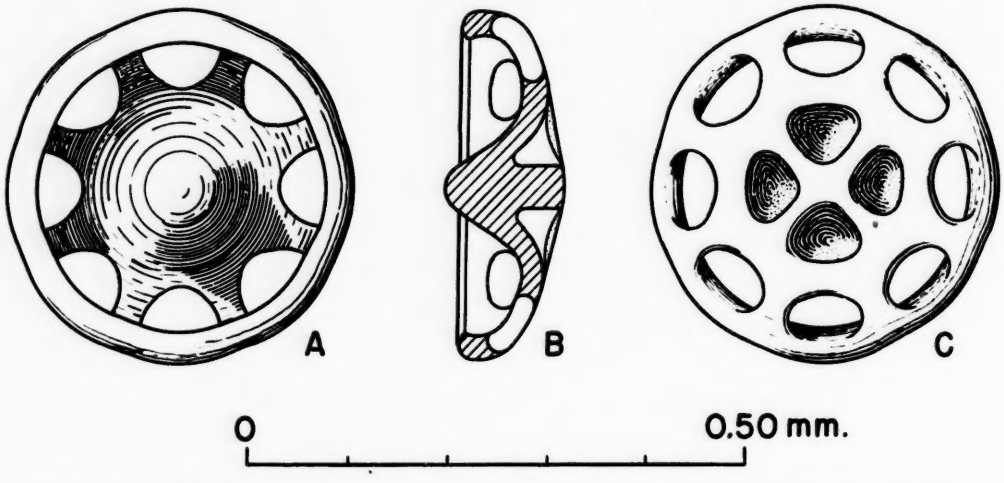
Microantyx, KORNICKER & IMBRIE, 1958, p. 93, pl. 1, figs. 1–6.

Description.—Sclerite in form of wheel, size variable depending upon growth stage; outline remarkably constant and consistent, generally circular with some slight marginal undulations, shallow scallops conform to interspoke periphery; 8 short, strong spokes; interspoke spaces low, strongly arched on inner sides, slightly arched on outer sides; sclerite is dished generally concavo-convex except for prominent central hub on upper side and slightly rounded, strong incurved, smooth, raised rim; the hub has conical sides with smoothly rounded central portion which usually extends above plane of the rim; the lower surface has 4 centrally arranged depressions which do not penetrate through sclerite but appear to be fairly deep although they are usually filled with rock; an occasional sclerite has been found which has 5 depressions; the arrangement of the depressions produces an X-shaped ridge between them; hub surrounded by 8 low septa separating deeply excavated oval interspoke areas. The perforated interspoke areas are uniformly 8 in number.

Dimensions.—Measurements of two specimens chosen from over one hundred are as follows:

	U.S.N.M. 137040	U.S.N.M. 137039 (Holotype)
Max. diam.	0.32 mm.	0.34 mm.
Thickness (less hub projection)	0.08	0.10
Thickness, total	0.10	0.12
Max. diam. of perforations	0.05	0.05
Least diam. of perforation	0.04	0.04
Max. diam. of hub	0.18	0.20

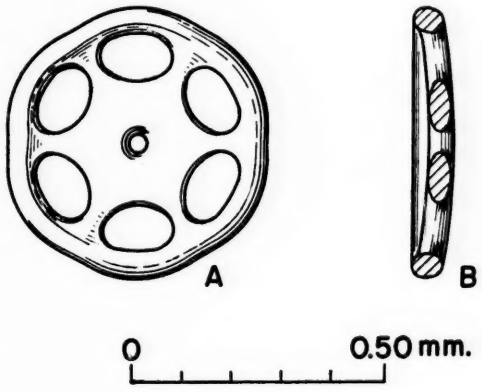
Remarks.—This unique sclerite is characterized by having a prominent raised hub on one side, 4 central depressions on the opposite side which do not pierce sclerite, 8 interspoke perforations, and uniformity of these characters. It has the appearance of an ornamental shirt button hence the specific name. It is very abundant in the Rockford shale partings. It differs quite markedly from *Paleochiridota plummerae* in having a prominent raised hub, lacks serrations along inner portion of the rim, lacks central depression on lower side, has 8 interspoke



TEXT-FIG. 3—Sketch of *Microantyx botoni*, n. sp. A, upper view. B, section through side view to show relation of depressions to raised hub. C, lower view.

spaces instead of 6, and has greater regularity of the 4 central depressions. *M. botoni* resembles *Paleochiridota primaeva* (Etheridge) from the Carboniferous of Scotland (1881, pl. VI, fig. 4) in general form and number of perforations except the latter lacks the raised hub and opposing 4 central depressions. It also has a more scalloped outline. *Paleochiridota? robertsoni* from the Lower Carboniferous of Scotland also lacks the central raised hub and depressions. *M. botoni* differs from the genotype, *M. permiana* of the Permian of Kansas, in having 8 spokes rather than 10; and extends the range of genus from Mississippian to Permian.

Types.—Holotype, U.S.N.M. 137039; paratype, U.S.N.M. 137040.



TEXT-FIG. 4—Sketch of *Rota campbelli*, n. sp. A. upper view. B, cross-section of side view.

ROTA CAMPBELLI, n. sp.

Pl. 26, figs. 1–21,26,27,32–35; text-fig. 4

Rota martini LANGENHEIM & EPIS, 1957, p. 170, pl. 1, figs. 17,18,20,23,25; not figs. 19,21,22,24.

Description.—Sclerite is a concavo-convex wheel; great variability in size and shape; shape more commonly subhexagonal but varies from subround to hexagonal to octagonal to irregularly polygonal; sides vary from straight to strongly scalloped (pl. 26, figs. 1–21,26,27,32–35, shows variability); interspoke perforations vary in number from 5 to 8, most commonly sclerites have 6 perforations; consequently number of radial spokes vary also from 5 to 8; shape of interspoke perforations vary from subtriangular to suboval; these are bounded outwardly by a bold, smooth rim which forms the margin of the sclerite; most if not all have a small perforation in the center of the large plain hub which is not raised; the central perforation is often filled with material so as to obscure it. Over 200 specimens were extracted from the samples for study.

Dimensions.—Due to the great variability of this species, a larger number of specimens was used in the illustrations and measurements to give the latittude of dimensions.

Remarks.—Prof. Langenheim furnished paratypes of *Rota martini* for comparison. The Escabrosa sclerites contain forms which have a single cycle of perforations around a centered perforation and also others which have a second cycle of perforations around the margin. The sclerite morphological development suggested by Langenheim & Epis for *Rota martini* has not been observed in the Rockford material. *Rota campbelli* is very abundant in the Rockford and has the variability illustrated in plate 26. No specimens were observed which have a second cycle of perforations. Since Langenheim & Epis chose a plate with more than one cycle

U.S.N.M. No.	Max. diam.	No. of spokes	Hub Max. diam.	Perforations Max. diam.	Perforations Min. diam.	Thickness	Diam. central perforation
137018	0.36	6	0.17	0.08	0.06	0.06	0.02
137019	0.40	6	0.17	0.08+	0.06	0.07	0.04
137020	0.41	6	0.19	0.10	0.07+	0.11	—
137021	0.44	6	0.19	0.09+	0.07+	0.12	0.03?
*137022	0.54	6	0.26	0.11+	0.08+	0.11	0.03
137023	0.55	6	0.27	0.14	0.08+	0.11	0.04
137025	0.32	6	0.14	—	0.04	0.07	—
137030	0.38	5	0.16	0.08+	0.07+	0.06	—
137033	0.40	7	0.17	0.06	0.04+	0.10	—
137036	0.37	8	0.17	0.08	0.05+	0.07	—

* Holotype.

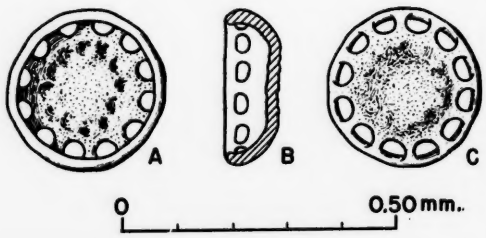
of perforations as the holotype of *Rota martini* and that some of the paratypes appear to be identical with Rockford forms, it was decided to place these in a new species of the genus *Rota*. The species name honors Guy Campbell whose careful stratigraphic work on Devono-Mississippian units is recognized.

Types.—Holotype, U.S.N.M. 137022; Paratypes, U.S.N.M. 137018–137021, 137023–137038.

NEW GENUS?, NEW SPECIES

Pl. 26, figs. 24,25,30,31; text-fig. 5

Two small, fragmentary sclerites were found which differ from all others in the collection. They are simple, circular, concavo-convex plates which bear 12 perforations around a rimmed border. The central hub is thin, imperforate, and bears irregularities which deviate from its flatness. The sclerite is generally small, less than 0.35 mm. in maximum diameter. The two figured specimens were lost and in the absence of adequate type material, no attempt is made to establish this as a new form although it is clear that the specimens do not fit any described material. A few additional fragmentary specimens were found which indicate a variability in the number of perforations from 10 to 12. This material is most similar to *Paleochiridota primaeva* (Etheridge), especially Etheridge's figs. 5–8 on plate VI. They compare well in size and number of perforations but the Rockford specimens lack the undulating margin of the Scottish forms.



TEXT-FIG. 5—Sketch of new genus? new species. A, upper view. B, cross-section of side view. C, lower view.

OTHER MATERIAL

Three small specimens were found which are in the form of a cylindrical rod slightly curved with small enlarged knobs at each end (text-fig. 6). They are similar to the fossil sclerites *Rhabdotites mortenseni* Deflandre-Rigaud from the Jurassic of Germany except the Rockford specimens are composed of milky, translucent chalcedony. It would appear that they are siliceous sponge spicules similar if not identical to *Reniera clavata* described by Hinde (1881, p. 143, pl. IX, fig. 5a,b) from the Yoredale series of the British Isles. It is possible that the silica is merely replacement of calcite; however none of the other sclerites were silicified.

EXPLANATION OF PLATE 25

All figures ×50; photos retouched

FIGS. *1,5—Thuroholia mccormacki* (Frizzell & Exline). U.S.N.M. 136998, 136999.

2,6—Thuroholia marginata Langenheim & Epis. U.S.N.M. 137000, 137001.

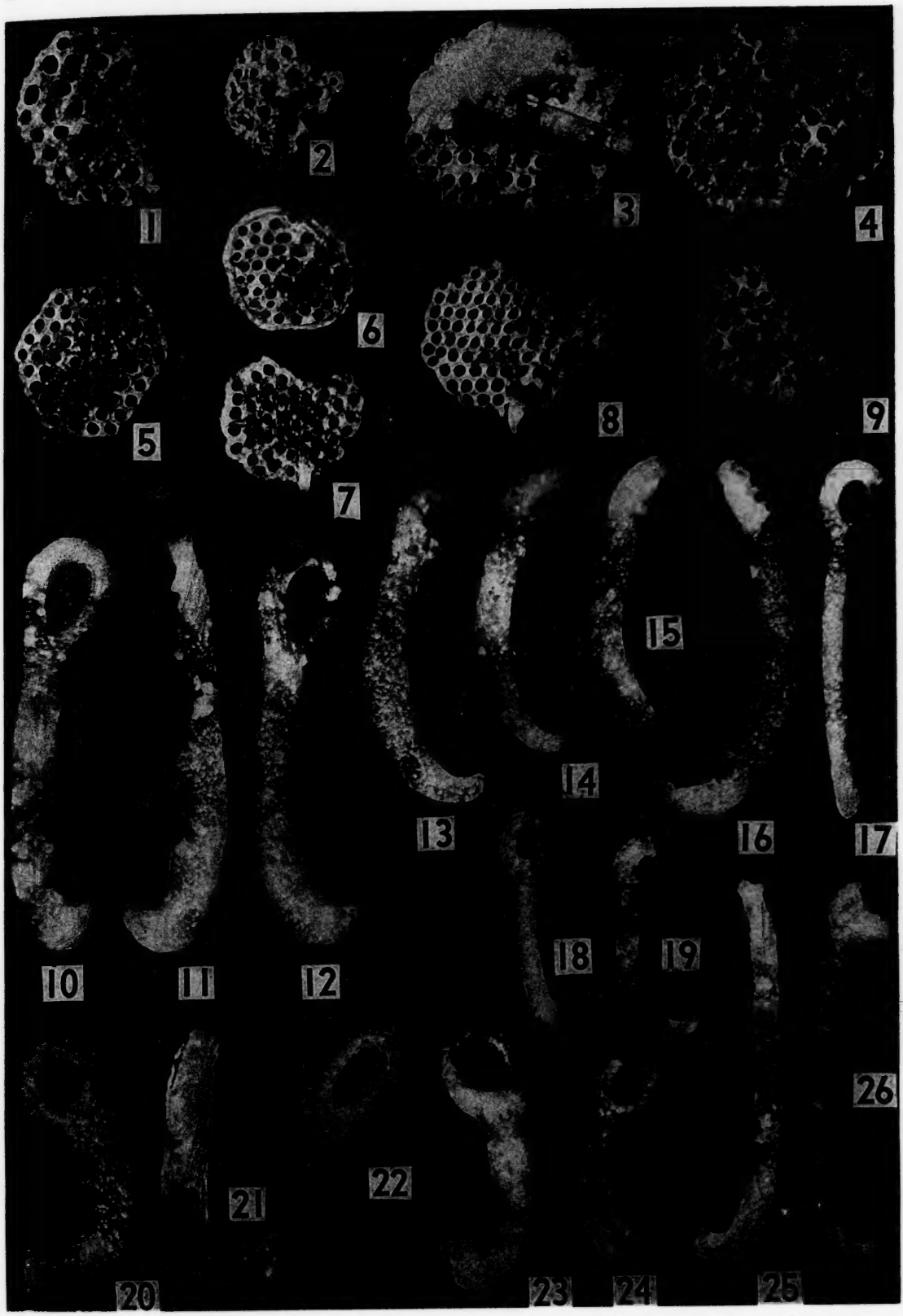
3,4,7–9—Thuroholia spicatus, n. sp. *3,4*, holotype, showing both sides of sclerite; *3*, shows *Achistrum* shaft cemented to plate, U.S.N.M. 137002. *7,8*, and *9*, paratypes showing scalloped margin and marginal spine. U.S.N.M. 137003, 137004, 137005.

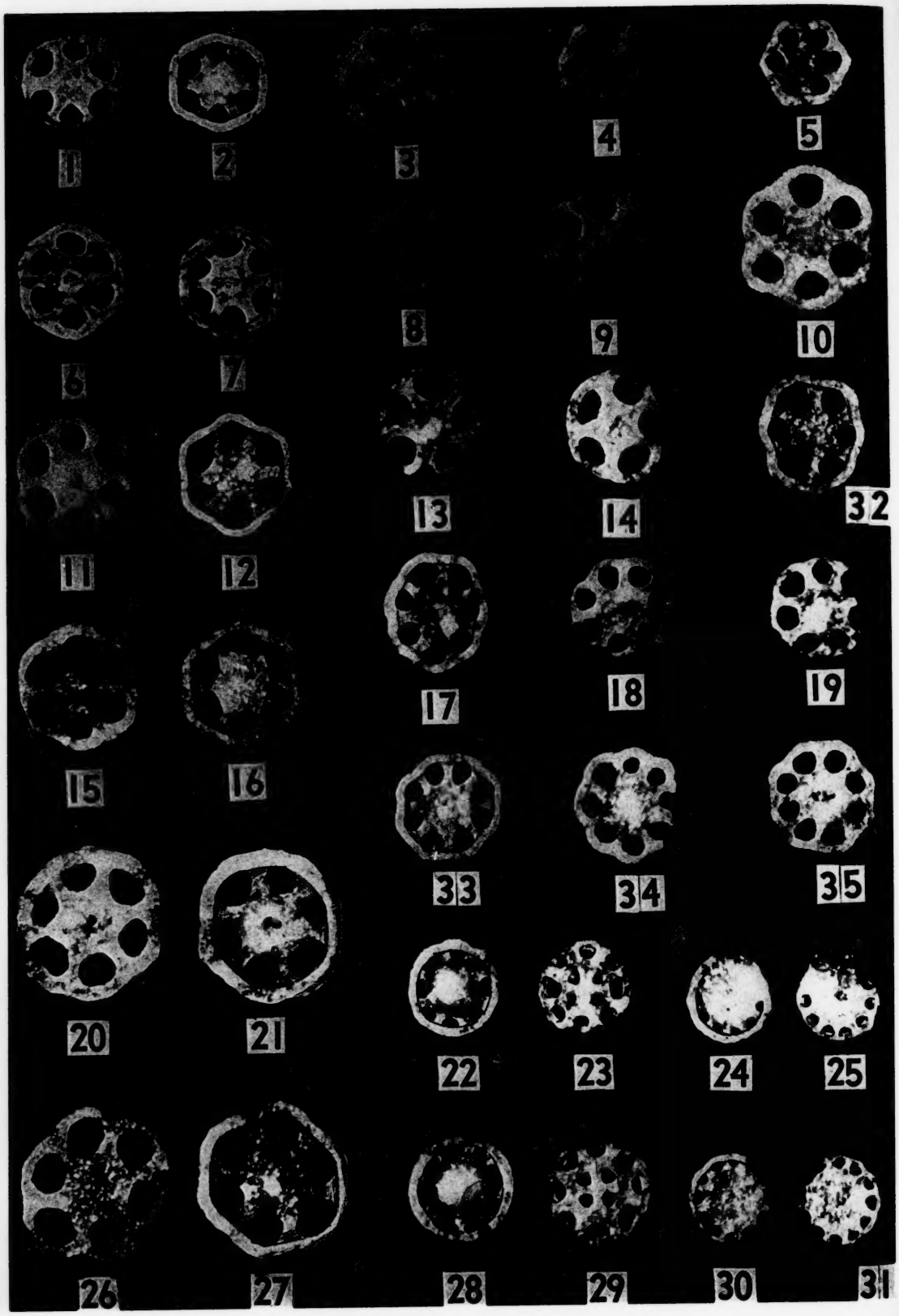
10–12—Achistrum nicholsoni Etheridge. *10*, front view; *11*, lateral view; *12*, oblique view, U.S.N.M. 137006.

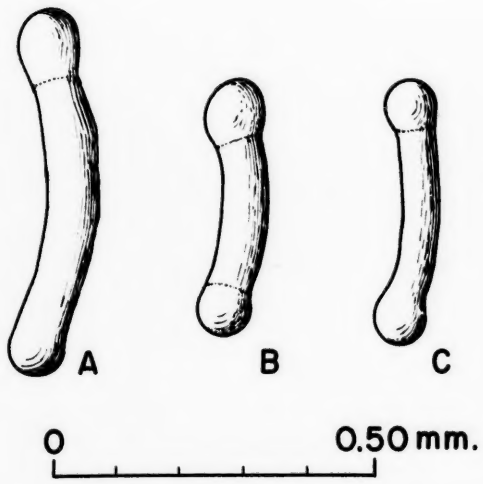
13–19—Achistrum ludwigi (Croneis). *13,14,15*, lateral views, U.S.N.M. 137007, 137010, 137008; *16*, lateral view, *17*, front view, U.S.N.M. 137012; *18*, fragmentary specimen to illustrate eye, U.S.N.M. 137009; Oblique view, U.S.N.M. 137011.

20–24—Achistrum brevis, n. sp. *20,21*, holotype, front and lateral views, U.S.N.M. 137013; *22*, front view showing shaft and spear twisted to right, U.S.N.M. 137014; *23*, front view showing shaft and spear twisted to left as in holotype, U.S.N.M. 137015; *24*, front view, U.S.N.M. 137016.

25, 26, Achistrum triassicum? Frizzell & Exline. *25*, lateral view; *26*, front view, U.S.N.M. 137017.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26


1
2
3
4
5
6
7
8
9
10
11
12
13
14
32
15
16
17
18
19
20
21
33
34
35
22
23
24
25
26
27
28
29
30
31



TEXT-FIG. *6*—Sketch of sponge spicules associated with holothurian sclerites.

Measurements.—Length 0.43 to 0.58 mm.; diameter of shaft, 0.07 to 0.085 mm.; diameter of knobs, 0.10 mm.; diameter of neck, 0.07 mm.

REFERENCES

CAMPBELL, GUY, 1956, New Albany shale and Kinderhook Series in Indiana: Geol. Soc. America, v. 67, p. 1679 (Abstract).

CRONEIS, CAREY, & MCCORMACK, JOHN, 1932, Fossil Holothuroidea: Jour. Paleontology, v. 6, no. 2, p. 111–148, pls. 15–21, 4 text-figs.

ETHERIDGE, R., 1881, On the presence of scattered skeletal remains of Holothuroidea in the Carboniferous limestone series of Scotland: Roy. Phys. Soc. Edinburgh, Proc., v. 6, p. 183–198, pls. 5,6.

FRIZZELL, D. L., & EXLINE, HARRIET, 1955, Monograph of fossil holothurian sclerites: Univ. Mo. Sch. Mines & Metallurgy, Bull., Tech. Ser. No. 89, 204 p., 11 pls., 21 text-figs.

GUTSCHICK, R. C., 1954, Holothurian sclerites from the Middle Ordovician of northern Illinois: Jour. Paleontology, v. 28, no. 6, p. 827–829, figs. 1–19.

——, & TRECKMAN, JOHN F., 1957*a*, Lower Mississippian cephalopods from the Rockford limestone of northern Indiana: Jour. Paleontology, v. 31, no. 6, p. 1148–1153, pls. 143–144, 3 text-figs.

——, & ——, 1957*b*, Arenaceous foraminifera from the Rockford limestone of northern Indiana: Geol. Soc. America, v. 68, no. 12, pt. 2, p. 1892 (Abstract).

HINDE, G. J., 1888, A Monograph of the British Fossil Sponges, Pt. II, Palaeontographical Society, p. 93–188.

KORNICKER, LOUIS, & IMBRIE, JOHN, 1958, Holothurian sclerites from the Florena shale (Permian) of Kansas: Micropaleontology, v. 4, no. 1, pp. 93–96, pl. 1.

LANGENHEIM, R. L., JR., & EPIS, R. C., 1957, Holothurian sclerites from the Mississippian Escabrosa limestone, Arizona: Micropaleontology, v. 3, no. 2, p. 165–170, pl. 1, text-fig. 1.

MARTIN, W. R., 1952, Holothuroidea from the Iowa Devonian: Jour. Paleontology, v. 26, no. 5, p. 728–729, 2 text-figs.

WORKMAN, L. E., & GILLETTE, TRACEY, 1956, Subsurface Stratigraphy of the Kinderhook series in Illinois: Ill. Geol. Surv., Rept. Invest. 189, 46 p., 2 pls., 20 figs.

MANUSCRIPT RECEIVED APRIL 20, 1958.

EXPLANATION OF PLATE 26

All figures ×50; photos retouched

FIGS. *1–21,26,27,32–35*—*Rota campbelli*, n. sp. *10–21*, holotype, U.S.N.M. 137022; *1,2,6,7,11,12,15,16, 26,27*, typical representatives of species showing 6 perforations, U.S.N.M. 137018, 137019, 137020, 137021, 137023; *3–5*, hexagonal-shaped variants, U.S.N.M. 137024, 137025, 137026; *8–10*, scalloped margin forms, U.S.N.M. 137027, 137028, 137029; *13–14*, sclerites with 5 perforations, U.S.N.M. 137030, 137031; *32*, oblong form, U.S.N.M. 137032; *17–19*, forms with 7 perforations, U.S.N.M. 137033, 137034, 137035; *33–35*, octagonal forms with 8 perforations, U.S.N.M. 137036, 137037, 137038.

22,23,28,29—*Microantyx botoni*. n. sp. *22,23*, upper and lower views of paratype, U.S.N.M. 137040; *28,29*, holotype, upper and lower views, U.S.N.M. 137039.

24,25,30,31—New genus? new species.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 138–160, PL. 27, 6 TEXT-FIGS., JANUARY 1959

DEVONIAN TETRACORALS FROM SOUTH DEVONSHIRE, ENGLAND

GERARD V. MIDDLETON
McMaster University, Hamilton, Canada

ABSTRACT—This paper describes the tetracoral fauna of several masses of limestone of Middle and Upper Devonian age, in South Devonshire, England. The fauna consists mainly of Ancanthophyllid, Stringophyllid and Disphyllid corals: Cystiphyllid corals were also abundant, but are not described in this paper.

INTRODUCTION

THE corals described in this paper were all collected by the author in the course of mapping an area of Middle and Upper Devonian rocks, near Newton Abbot in South Devonshire, England. Previous paleontological work on specimens from this area, or from adjacent areas, was by Lonsdale (1840), Phillips (1841), Davidson (1864, 1865), Champernowne (1878, 1881, 1884), Whidborne (1889–1907), Nicholson (1886–1892) and others. However, the corals received little attention, in spite of their abundance in many localities, because they were mostly assigned to a few species within the "sack" genus *Cyathophyllum*.

Recently, Taylor (1950, 1952) has made a study of tetracorals from the nearby localities of Plymouth and Torquay in South Devon.

The work published in this paper was carried out while the author held a grant from the Department of Scientific and Industrial Research. The author also wishes to thank Drs. Dighton Thomas, Peter Taylor and others who have permitted him access to their collections, or who have assisted him by their advice and criticism.

MATERIAL AND TECHNIQUE

The Devonian rocks of South Devon were folded and slightly metamorphosed in the Variscan orogeny. The argillaceous rocks were converted into slates and the limestones were recrystallized. Fossils in the limestones are frequently not well preserved, and in some places dolomitization has destroyed original textures. It is rarely possible to extract corals from the matrix of limestone: hence the external features are almost invariably unknown. It is also very difficult to obtain specimens in which the early growth stages are preserved: hence no ontogenetic studies have been undertaken. The specimens are commonly distorted as a result of the deformation of the enclosing rock, and this deformation makes it difficult to obtain a true cross-section, for in a distorted specimen the true cross-section is no longer a plane normal to the axis, and the enveloping matrix conceals the growth lines.

Most of the corals have been examined by means of cellulose transfers taken from smooth plane surfaces which have been etched in hydrochloric acid, following the technique described by Butler (1935). The advantages of this method over thin sections lie in the increased speed and facility and in the fact that less of the specimen need be destroyed. The disadvantage of the method lies in the fact that it is not possible to examine the microskeletal elements of the coral skeleton. However, in many cases the corals are not sufficiently well preserved that thin section study would yield much additional information.

Notwithstanding these observations, fairly well preserved specimens were found, and about 250 thin-sections and transfers were examined. The collection is deposited in the Murchison Museum, Imperial College, London, England.

CLASSIFICATION

The modern phase in the development of knowledge of the Devonian rugosa may conveniently be considered as opening with the work of Wedekind (1922 onwards). For a review of earlier classifications see Sanford (1939).

In 1922 Wedekind classified the rugosa of the Eifel, Germany, into two main familes, the Cyathophyllidae and the Campophyllidae. In 1924 and 1925 he modified his earlier classification, introducing at the same time a number of inconsistencies, which Kettnerova attempted to remove in 1932. However, her work was shortly preceded (1931) by Wedekind and Vollbrecht's detailed study of the "Lytophyllidae" of the Middle Devonian of the Eifel. The familial classification at this time was as follows:

Lytophyllidae Wdkd. & Vollbrecht 1931
Digonophyllidae Wdkd. 1924
Ptenophyllidae Wdkd. 1924
Stenophyllidae Wdkd. 1924
Stringophyllidae Wdkd. 1925
Phacellophyllidae Kettnerova 1932
Campophyllidae Kettnerova 1932
Glossophyllidae Kettnerova 1932
Pexiphyllidae Walther 1928

A number of families were also established by subsequent workers, and in 1939 Sanford produced a general classification of all tetracorals. Sanford's classification was not satisfactory for Devonian corals, which were first treated comprehensively by Stumm (1949). The technique of microscopic examination of the coral skeleton has been developed since Wedekind's work, notably by Hill (1936); and Wang (1951) was the first to propose a complete classification of tetracorals based on their minute skeletal structures. Soshkina (1951) has also advanced a comprehensive classification of tetracorals, based mainly on studies of ontogeny. Since the author's work was completed (in 1954), two further classifications have been proposed (Lecompte 1952, Hill 1956).

There is, therefore, no lack of classifications, but unfortunately there is also no lack of variety. The disagreements on classification derive from the familiar paleontological difficulties: there are few accepted criteria for classification and often the structures of the fossils have been variously interpreted in the light of different theories (cf. especially the 'Cystiphyllids'). The interpretation of the scope of genera and species also gives rise to confusion. Thus Hill (1942) included five of Wedekind's genera within her genus *Digonophyllum* and nine of his genera within her genus *Mesophyllum*.

The classification used here is based on those of Wedekind and Stumm. Taylor (1952 MS) has made a detailed study of the group of corals called by Wedekind the Lytophyllids and Digonophyllids, based on rich faunas in South Devon, and a re-examination of Wedekind & Vollbrecht's work and of material collected in the Eifel. The author worked independently of Taylor, but in so far as this group has been studied, he is in agreement with all Taylor's main conclusions. It is, however, proposed to defer publication of descriptions of corals belonging to this group to a later paper.

ZONAL SCHEMES BASED ON TETRACORALS

The main purpose in undertaking the study of tetracorals from the Newton Abbot area was to throw light on the stratigraphy and correlation of the Devonian limestones. At the majority of localities in Devonshire, it is impossible to extract fossils from their matrix: hence brachiopods and molluscs become practically useless for stratigraphic purposes and recourse must be made to those fossils that may be recognised in cross-section, namely tetracorals, tabulate corals and stromatoporoids.

Of these, the tetracorals have been intensively studied by Wedekind (1924, 1925) who set up a zonal scheme for the Middle and Upper Devonian of the Eifel. Hence it was proposed to use the paleontological sequence as established in the Eifel by Wedekind (1923, 1924, 1925, 1934, 1937) and his school (Wedekind & Vollbrecht 1931, 1932; Walther 1928, Haller 1935, Vollbrecht 1922, 1926), as a standard, with which the less thoroughly investigated Devonshire faunas might be compared.

When this was attempted a number of difficulties arose. Wedekind's work, both stratigraphic and paleontologic, is in need of revision. The stratigraphy of the Eifel has recently been revised by Richter (1952) and others (Krömmelbein et al., 1955), but a thorough revision of Wedekind's paleontological work has not yet appeared. Nevertheless, Soshkina (1936) has used a modified form of Wedekind's zonal scheme in the North Urals, and Taylor (1950) showed that it could also be used in Devonshire. Some criticism of the scheme has been made by

Kettnerova (1932), who described an upper Middle Devonian fauna which contained species believed by Wedekind to be characteristic of the lowest Middle Devonian, and also by Schmidt (1936).

Undoubtably Wedekind's scheme is open to serious criticism. Few of Wedekind's species were as short ranged as he believed. By all subsequent evaluation, Wedekind was an ardent "splitter," with little regard for the International rules of Zoological Nomenclature (as he himself admits; Wedekind 1925). His approach was essentially stratigraphic, and he did not concern himself with a detailed revision of the earlier work in the Eifel of Goldfuss, Frech, Römer, Schlüter and others. Indeed, he occasionally ignored his own early work in later papers. For example, in 1925 Wedekind selected *Cyathophyllum isactis* Frech, as type species of *Grypophyllum*, although in 1922*a* he had already designated *G. denckmanni* as the type species. Another difficulty arises owing to his tendency to be influenced in his paleontological work by his theories of biostratigraphy. For example, the specimens figured by Wedekind (1925, pl. 11, text-figs. 66–69) are clearly Acanthophyllids, but because of their high stratigraphic position they were called by Wedekind *Neostringophyllum* sp. Notwithstanding these criticisms, Wedekind's work was a spectacular advance on all previous work on Devonian corals, and formed the base upon which all subsequent work on Devonian corals in Europe and Asia has been built. Wedekind's scheme is outlined in his papers of 1924, 1925 and 1937, and a much simplified version is shown in table 1. The following are the main modifications which it is believed are necessary in the light of subsequent work.

(a) Grypophyllids, though characteristically developed in the Sp-zone, are also found at much lower horizons (Schmidt 1926, Wang 1948).

(b) Digonophyllids may be found even as high as the upper Middle Devonian (Kettnerova 1932, Haller 1935).

(c) The base of the middle Middle Devonian cannot be regarded as being marked by the extinction of the "Ptenophyllids" (which are roughly equivalent to the Acanthophyllids), since these are found at higher horizons, both in the Eifel and in Devonshire (Schmidt 1936, Taylor 1950).

TABLE 1—WEDEKIND'S ZONAL SCHEME

Upper Middle Devonian

Dy—*Dialytophyllum* zone: Stringophyllids are still present, with *Schizophyllum*, *Dialytophyllum*, *Neostringophyllum*, *Spinophyllum*.

Middle Middle Devonian

Sp—*Sparganophyllum* zone: *Sparganophyllum* has replaced *Stenophyllum:* there is a rich fauna of Lytophyllids: Stringophyllids are abundant and include *Stringophyllum*, *Neospongophyllum* and *Schizophyllum*.

Upper Sp-zone: *Neospongophyllum* and *Stringophyllum* are abundant, together with thin septate Gryophyllids.

Lower Sp-zone: *Neospongophyllum* is rare and *Loipophyllum* is relatively abundant.

St—*Stenophyllum* zone: Many species of *Stenophyllum*. Lytophyllids are abundant. *Loipophyllum* may be abundant but other Stringophyllids are rare.

L—*Leptoinophyllum* zone: *Leptoinophyllum* abundant but with few species. The Acanthophyllids have disappeared. Lytophyllids occur but are not particularly abundant.

Lower Middle Devonian

Do—*Dohmophyllum* zone: Keriophyllids have disappeared and Trematophyllids are replaced by Dohmophyllids.

The top of the zone is marked by the extinction of the Acanthophyllids.

In Devonshire, the most prolific and widespread faunas occur in argillaceous crinoidal limestones of the St- and Sp-zones, at the base of the main limestone sequence. Well preserved faunas from higher horizons do exist, but are rarer because the pure biohermal limestones at these stratigraphic levels are commonly more thoroughly recrystallized. Furthermore, the facies is commonly one in which stromatoporoids and tabulate corals are more abundant than tetracorals (such ecological control has recently been very clearly demonstrated for the Upper Devonian of Belgium by Lecompte, 1956).

K—*Keriophyllum* zone: The Acanthophyllids reach their acme with the carinae becoming their dominant characteristic: *Keriophyllum*, *Trematophyllum*, *Rhopalophyllum*.

A—*Astrophyllum* zone: Only the older Acanthophyllids are present. *Astrophyllum* is dominant. Zonophyllids and Digonophyllids are quite abundant.

D—*Digonophyllum* zone: Only the simpler

Dignopyllids are present. Simple *Acanthophyllum* dominates. *Zonophyllum* is common.

Note: In most cases Wedekind's generic names are used here. Many are invalid, or are normally lumped together with other genera. The scheme has been greatly simplified from Wedekind, 1924 and 1925.

SYSTEMATIC PALEONTOLOGY

Family PTENOPHYLLIDAE Wedekind 1923

Acanthophyllidae HILL 1939*a*.

Remarks.—Wedekind believed that the Ptenophyllidae were characteristic of the lower Middle Devonian and did not extend above the Do-zone, but this hypothesis was not supported by subsequent work. The family is restricted to the Middle Devonian: hitherto no forms which may be safely assigned to this family have been described from America, but it is very important in Europe.

Genus ACANTHOPHYLLUM Dybowski, 1873

Acanthophyllum DYBOWSKI, 1873, p. 339; 1874, p. 493.
Mesophylloides WEDEKIND, 1922*b*, p. 51.
Ptenophyllum WEDEKIND, 1923, p. 26.
Astrophyllum WEDEKIND, 1924, p. 45.
Rhopalophyllum WEDEKIND, 1924, p. 52.

Type species.—By subsequent designation of Schlüter (1889, p. 296), *Cyathophyllum heterophyllum* Ed. & H. 1851, p. 367, pl. 10, figs. I,1a,1b, from the Middle Devonian of the Eifel.

Generic description.—Simple subcylindrical corals with a typical Acathophylloid calice. The septa are dilatated in the early stages of the ontogeny, and in the ephebic stages retain dilatation in their central parts. The septa attenuate towards the periphery, and may break down into strands distally ("Abspaltung" of Wedekind). The major septa reach the axis where they may show a slight bilateral symmetry (*Ptenophyllum* and *Astrophyllum*) or they may show a well developed axial whorl (*Rhopalophyllum*). Carinae may be well developed, especially at the axis, and the septal ends may be rhopaloid. The minor septa are thin and may not show any signs of dilatation: they extend from the periphery to the border of the tabularium. The tabularium is composed of tabellae and is sharply differentiated from the dissepimentarium, which is wide and composed of many rows of small inflated dissepiments, which are nearly horizontal near the periphery but become steeply axially inclined towards the tabularium.

ACANTHOPHYLLUM sp. cf. A. FIBRATUM Wedekind
Text-fig. 1a,c.

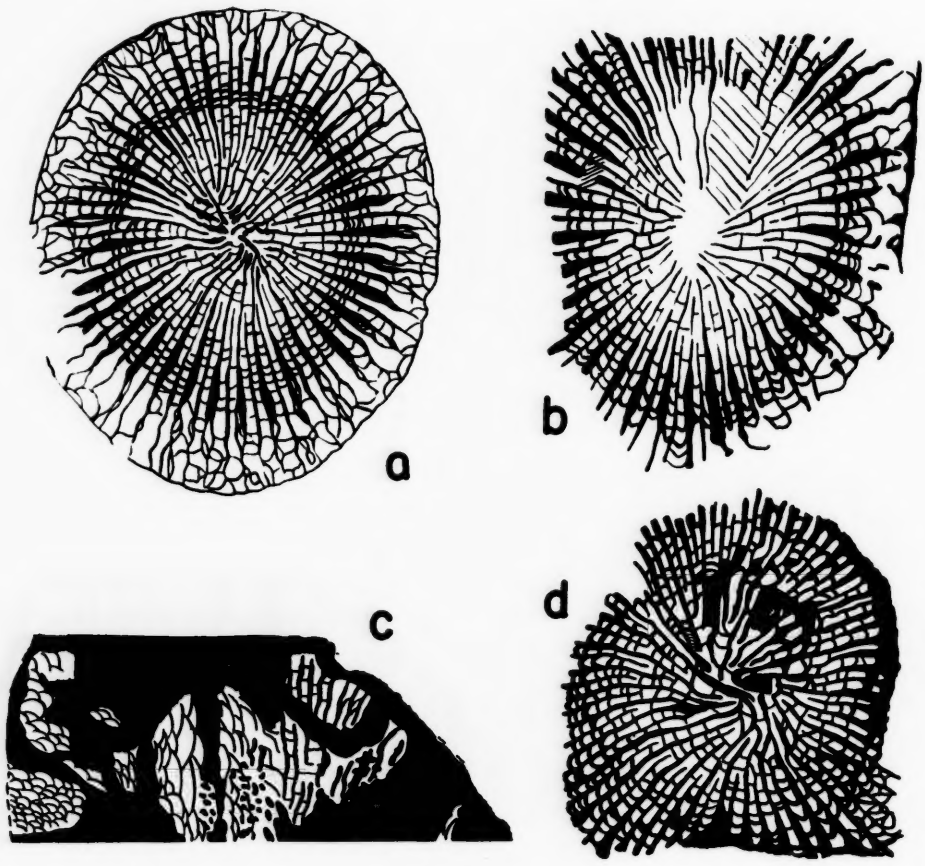
Cf. *Rhopalophyllum fibratum* WEDEKIND, 1924, p. 52 and 61, text-figs. 76–79 on p. 51, and (?) text-figs. 80–82 on p. 53, and text-fig. 97 on p. 62.
Cf. *Acanthophyllum* cf. *fibratum* TAYLOR, 1950, p. 165, pl. 1, figs. 2a,2b.

Acanthophyllum with thin epitheca. Septa thin at periphery, thicker towards the center, and thin again at the border of the tabularium. Septal ends have a rough bilateral symmetry and are slightly rhopaloid and carinate. A slight curving of the septal ends is common and there is every transition from forms with a marked bilateral symmetry to forms with a distinct axial whorl. There is a slight tendency for the septa to split up into strands near the periphery. The minor septa extend to the border of the tabularium and are about three-quarters of the length of the major: they also are slightly dilatated in their central parts. The septa are very attenuated near the periphery and tend to become lost among the peripheral dissepiments. The diameter is 2–3 cms. and there are 64–80 septa.

Occurrence.—Several specimens from the St-zone of Chercombe Bridge (NGR[1] 20/833711) and one from Old Quarry SW of Halwell (NGR 20/824679).

Remarks.—These specimens differ from *A. fibratum* (Wedekind) in the very thin epitheca and in the absence (in the better preserved specimens) of an axial whorl. *A. gerolsteinense* (Wedekind, 1924) is close to some of the specimens, especially Wedekind's fig. 74 on p. 47. The specimens differ from *A. gerolsteinense* in the presence of carinae, splitting of the septa, and the somewhat greater dilatation of the septa (though the dilatation is usually rather less than in the typical *A. fibratum*). The variation observed suggests that the presence or absence of a slight axial whorl cannot be considered even a specific criterion.

[1] National Grid Reference.



TEXT-FIG. *1*
(All figures ×2½)
1a, c, Acanthophyllum sp. cf. *A. fibratum* Wedekind.
1b, Acanthophyllum sp.
1d, Acanthophyllum sp.

ACANTHOPHYLLUM sp.
Text-fig. 1b

Acanthophyllum with fairly thick outer wall. 72 septa: the major dilatate close to the periphery and attenuate axially. The minor dilatate only slightly and extend to the border of the tabularium: they are about ½–⅔ the length of the major. The tabularium is broad and the septa are very thin and non-carinate near the axis. There is no axial whorl.

Occurrence.—One small fragment east of Dartington Hall (NGR 20/803627), Givetian.

ACANTHOPHYLLUM sp.
Text-fig. 1d

Acanthophyllum with thick septa. The peripheral parts are not well preserved in any specimen. There are 74–78 septa. The axial ends of the major septa are fairly thick and may be slightly rhopaloid. There is no axial whorl. The minor septa are ½–⅔ the length of the major. Near the periphery the septa are very thick and may ever be touching. There are no carinae.

Occurrence.—Several specimens from the St-zone of New Ground Copse (NGR 20 /828627) and Loventor (NGR 20/846632).

Remarks.—This is a very unusual form, but seems clearly to be related to *Acanthophyllum.*

Family LEPTOINOPHYLLIDAE Stumm emend.

Stenophyllidae WEDEKIND 1925.
Leptoinophyllidae STUMM *ex parte* 1949; TAYLOR 1950.

Familial description.—Simple or weakly aggregated subcylindrical to ceratoid corals, with a funnel-shaped calice ("Trichterkelch" of Wedekind). Septa of two orders, thin and non-carinate. Minor septa may be discontinuous or absent, and a lonsdaleoid dissepimentarium may be present. Major septa usually extend to axis, where they may assume bilateral symmetry. Dissepimentarium well developed and filled with rather elongate, axially inclined dissepiments. Tabularium with horizontal or distally concave tabulae or tabellae. An axial notch may be developed.

Remarks.—Stumm included the Stringophyllidae as a subfamily.

Genus GRYPOPHYLLUM Wedekind 1922

Grypophyllum WEDEKIND, 1922*a*, p. 13; 1925, p. 14, *ex parte.*
Hooeiphyllum TAYLOR, 1950, p. 173.

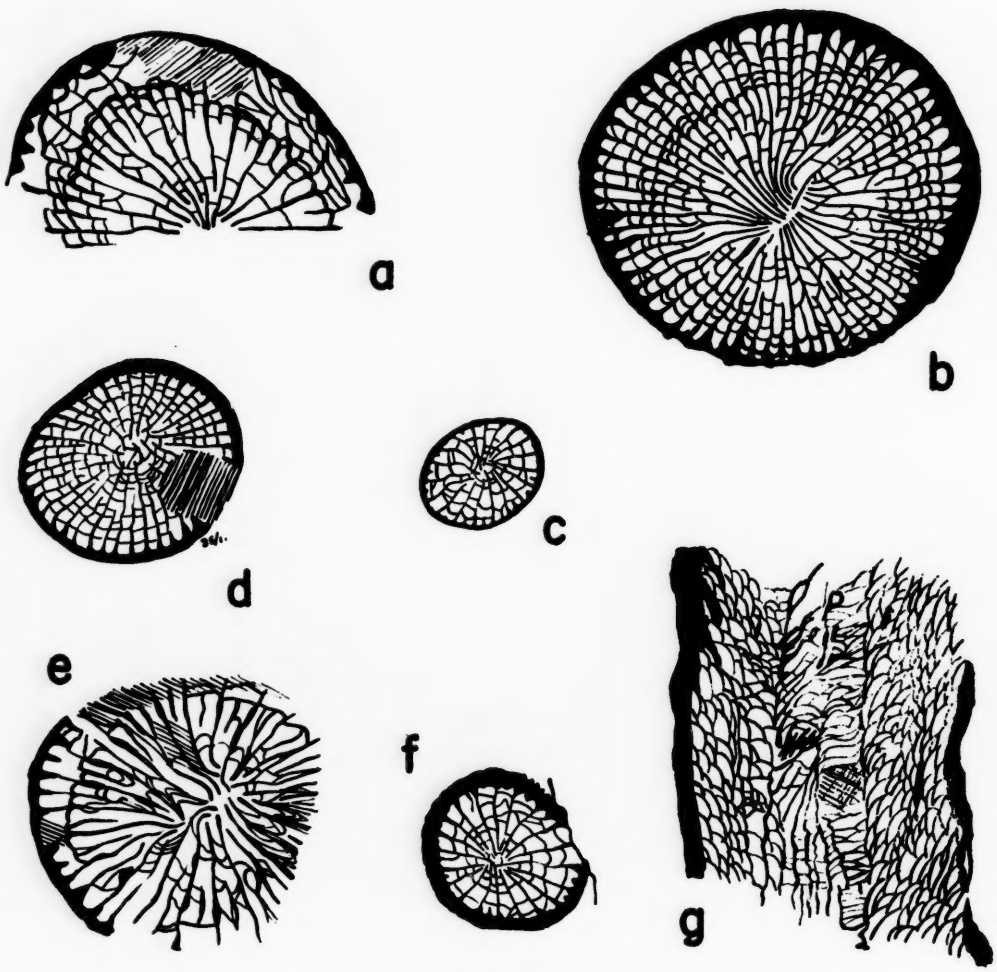
Type species.—By original designation, *G. denckmanni* Wedekind, 1922*a*, p. 13, text-figs. 13,14, on p. 14, form the Bücheler Schichten of Bergisch-Gladbach, Germany (upper Middle Devonian).

Generic description.—Simple or loosely aggregated subcylindrical corals. Septa radially arranged but may have a bilateral symmetry at the center: an axial whorl is never present. Septa usually very thin but may thicken towards the periphery: a thick outer wall is always present and is formed by lammellar tissue around the peripheral ends of the septa. Septa of two or occasionally of three orders. Major septa extend to the center, minor are shorter and may be represented only by rudimentary septa embedded in the outer wall. Lonsdaleoid dissepimentarium may or may not be present. Dissepimentarium wide, usually occupying about ⅔ diameter, and composed of several rows of highly inclined, rather elongate dissepiments, sharply differentiated from the tabularium, which is composed of nearly horizontal, complete or incomplete tabulae, in some cases with an axial notch.

Remarks.—In 1925 Wedekind named as type species *G. isactis* (Frech), but this designation is invalid in view of his previous designation of *G. denckmanni.* He also divided the genus into two groups. The first group, that of *G. isactis* (Frech) correctly belongs to the family Stringophyllidae (cf. Hill, 1939*b*, p. 59 and 1942, and Wang, 1948 p. 20). Taylor (1950) considers that those forms without lonsdaleoid dissepimentarium belong to a separate genus, *Hooeiphyllum* Taylor (type species: *G. normale* Wdkd, 1925). In view of the fact that the lonsdaleoid dissepimentarium is always poorly developed, and that even in the same specimen, septa which thicken towards the periphery may be seen in one sector of the cross-section and a lonsdaleoid dissepimentarium in another sector, *Hooeiphyllum* is regarded as a synonym of *Grypophyllum.* Grypophyllids have usually been described in the literature as "*Cyathophyllum vermiculare*" Goldfuss. *Strephodes gracilis* McCoy (1850, p. 378, see also McCoy, 1852, pl. 2A, figs. 5,5a,5b) is undoubtedly a *Grypophyllum;* hence a new specific name is required for *G. gracile* Wdkd, 1925 (see below). The genus *Battersbyia* Ed. & H. (1851, p. 151, p. 227; type species: *B. inaequalis* Ed. & H.) is here considered to be closely related to *Grypophyllum.* Duncan (1868) showed that the so-called "coenenchym" connecting the corallites, was in fact an encrusting stromatoporoid, associated with a fasciculate coral. The type species, *B. inaequalis,* is a very small form but the two forms described by Duncan (*B. grandis* and *B. gemmans*) are larger and have a relatively thick outer wall, very thin septa, thickened near the periphery and horizontal skeletal elements similar to those seen in simple Grypophyllids (e.g. *G. gracile* Wdkd). Both *B. inaequalis* and *B. gemmans* have been redescribed by Schindewolf (1941, p. 277–283, figs. 35–41 and pl. 1), who has shown that *Battersbyia* reproduced by calical or lateral increase, and that the peculiar mode of increase described by Duncan is not present.

GRYPOPHYLLUM TENUE Wedekind
Pl. 27, fig. 1; text-fig. 2f

Grypophyllum tenue WEDEKIND, 1925, p. 22, pl. 5, fig. 27.



TEXT-FIG. 2

(All ×2½ except as otherwise noted)

2a, *Grypophyllum* sp. cf. *G. regressum* Wedekind, ×3.
2b, *Grypophyllum tenue* Wedekind var.
2c,d, *Grypophyllum* sp. cf. *G. wedekindi* n. name.
2e, *Grypophyllum* sp. cf. *G. tenue* Wedekind.
2f, *Grypophyllum tenue* Wedekind.
2g, *Grypophyllum* sp.

The specimen agrees closely with Wedekind's figure and description. There are 50 septa and the diameter is about 20 mms., i.e., slightly larger than Wedekind's specimen.

Material.—One fragment, from Shinner's Bridge Quarry, Dartington (NGR 20 /789623), St- or Sp-zone.

GRYPOPHYLLUM sp. cf. G. TENUE
Wedekind
Text-fig. 2e

Tertiary septa are very slightly developed, being indicated by slight projections from the outer wall, between the first and

second order septa. The first order septa extend to the axis, the second order septa are about ⅔ as long and are complete. There are 42 septa of the first and second orders: diameter about 12 mms.

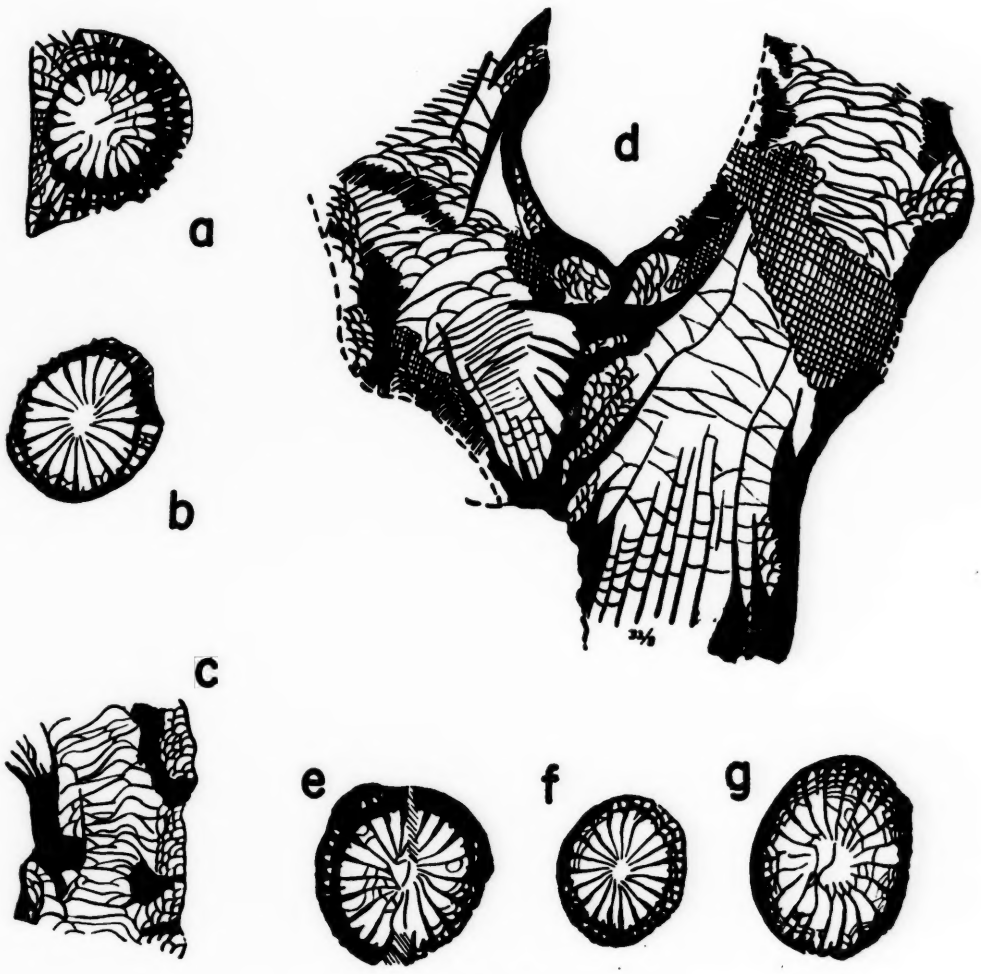
Occurrence.—One specimen from Quarry S.W. of Bradley Farm (NGR 20/839712): upper Middle Devonian.

Remarks.—Wedekind did not record tertiary septa from any of his specimens from the Eifel, but *Grypophyllum* with elementary tertiary septa are quite common in South Devon.

GRYPOPHYLLUM TENUE Wedekind var.
Pl. 1, fig. 2; text-fig. 2b

Grypophyllum with well-developed septa of two orders and occasional rudimentary tertiary septa. Septa thick at the periphery where there is a thick outer wall. Septa thin gradually towards the axis. Major septa reach the axis, where they are arranged with marked bilateral symmetry: minor septa are about half as long. 58–68 septa of first two orders.

Occurrence.—Two specimens from the up-



TEXT-FIG *3*

3a–g, Disphyllum caespitosum (Goldfuss) *var.* All ×2½ except for *3a*, which is ×2.

per beds at Chercombe Bridge (NGR 20 /833711): Sp-zone.

Remarks.—A faintly bilaterally symmetrical arrangement of the septa is indicated in Wedekind's figure of *G. tenue*. This is, however, the first example to be recorded of *Grypophyllum* in which there is marked bilateral symmetry: its presence serves to emphasize the affinities between the Grypophyllids and the Stringophyllids.

GRYPOPHYLLUM sp. cf. G. WEDEKINDI, n. name
Text-figs. 2c,d

Cf. *Grypophyllum gracile* WEDEKIND, 1925, p. 22, pl. 5, figs. 28,29; *non Strephodes gracilis* McCOY, 1850, p. 378, and McCOY, 1852, p. 72, pl. 2A, figs. 5,5a,5b.

Small Grypophyllum with thin major septa extending to the axis, and minor septa represented only by projections from the outer wall. The number of major septa varies from 18 to 27, and the diameter varies from 6 to 11 mms.

Occurrence.—One specimen from S.E. of Dartington Hall (NGR 20/801625), upper Sp-zone; one from Shinner's Bridge Quarry (NGR 20/789623), probably Sp-zone; several specimens from Chercombe Bridge NGR 20/833711), probably Sp-zone.

Remarks.—See above for the necessity of renaming Wedekind's species. The original of Wedekind's fig. 28 and 29 is here chosen as holotype of *Grypophyllum wedekindi* n. name. See also remarks under *G.* sp. cf. *G. normale* below.

GRYPOPHYLLUM sp. cf. G. NORMALE Wedekind
Text-figs. 4e,f

Cf. *Strephodes gracilis* McCOY, 1850, p. 378; and McCOY, 1852, p. 72, pl. 2A, figs. 5,5a,5b.
Cf. *Cyathophyllum robustum* MAURER, 1885, p. 95, pl. 2, figs. 1,1a,1b.
Cf. *Grypophyllum normale* WEDEKIND, 1925, p. 22, pl. 5, figs. 25,26.

One specimen shows part of a group of four corallites. The largest of these has a diameter of about 16 mms., and the smallest, 4 mms. The largest corallite agrees well with Wedekind's figure, but is smaller. The smaller corallites resemble *G. wedekindi*, n. name, the minor septa being absent. Another specimen has 26 or 27 major septa and the diameter is 11 mms. The minor septa are very short, the major are very thin and extend to the axis. The outer wall is very thick (about 1 mm. thick). The longitudinal section of the first specimen shows a narrow tabularium (about a quarter of the diameter of the corallite), consisting of slightly distally concave incomplete tabulae. The dissepimentarium is broad and consists of dissepiments which are elongate and strongly axially inclined.

Occurrence.—Two specimens from Chercombe Bridge (NGR 20/833711), St- or Sp-zone.

Remarks.—The second of the two specimens described is very close to *G. robustum* (Maurer), in so far as this species can be assessed from the imperfect figures and descriptions. The large corallite in the other specimen is close to *G. normale* Wedekind and the smaller ones to *G. wedekindi*, n. name. This suggests that there is a very close connection between all these species, and that some of the other specimens here identified as *G. wedekindi* may in fact be only young or small forms of *G. normale*. *Strephodes gracilis* McCoy is a *Grypophyllum* with minor septa "of irregular length but seldom extending one-fourth of the distance to the centre." The longitudinal section shows three rows of dissepiments in the dissepimentarium, not two as described by McCoy. McCoy mentions the "irregular complicated extremities" of the major septa, which are "very thin," but possibly this refers to the numerous sections through the tabulae as seen in cross-section, these sections being frequently concentrated in the axial region in *Grypophyllum*. *G. robustum* (Maurer) is probably conspecific with *G. gracilis*, though the minor septa are even less well developed: both represent intermediate forms between *G. wedekindi* and *G. normale*.

GRYPOPHYLLUM sp. cf. G. REGRESSUM Wedekind
Text-fig. 2a

Cf. *Grypophyllum regressum* WEDEKIND, 1925, p. 22, pl. 5, figs. 30,31.

Grypophyllum with irregular lonsdaleoid dissepimentarium. Major septa extend to axis, minor short and imperfectly developed,

usually less than half the length of the major. Where there is a lonsdaleoid dissepimentarium the minor septa may still be developed. Septa relatively thick; about 25 major septa are present. The specimens differ from Wedekind's figure in the better development of the minor septa.

Occurrence.—One specimen from Shinner's Bridge Quarry and one from the New Red Sandstone (Permian) breccias.

GRYPOPHYLLUM sp.
Text-fig. 2g

Cf. *Hooiphyllum* (?) sp. TAYLOR, 1950, p. 176, pl. 2, fig. 4.

Grypophyllum with relatively thick septa which may be irregularly thickened, for instance, at a short distance from the outer wall. Major septa extend from the outer wall, which is relatively thin for *Grypophyllum*, to the axis. The major septa do not show a gradual thinning towards the axis (as in *G. tenue*); they appear rather crowded at the axis. Minor septa may be one half to one third the length of the major, or may be discontinuous, occurring as septal crests. Occasionally they are absent. Rudimentary tertiary septa may be poorly developed in the outer wall. The number of major septa varies from 25 to 36 and the diameter varies from 12 to 17 mms.

Occurrence.—Three specimens from Chercombe Bridge (NGR 20/833711): St- or Sp-zone.

Remarks.—The irregular thickening of the septa has been observed in *Grypophyllum* by Taylor. His specimen, however, has well developed minor septa. The specimens here described are distinguished by their relatively thick septa, uniform in thickness apart from the irregular thickening, the crowding of the major septa at the axis, the irregular development of the minor septa, and the relatively thin outer wall. However, the material is inadequate for the designation of a new species.

Family STRINGOPHYLLIDAE Wedekind

Stringophyllidae WEDEKIND, 1922*a*, 1925.

Familial description.—Simple or weakly fasciculate subcylindrical or ceratoid corals. Septa thick, especially near the periphery where they may be invested with lamellar tissue. Major septa extend to axis where they may become attenuated: at the axis there is a marked bilateral symmetry and the septal ends may be somewhat t hckened. There is a tendency for the septa tobireak up into monacanths, especially the minor septa, and the major septa at the axis and near the periphery. Minor septa are usually incomplete and may be completely absent. A lonsdaleoid dissepimentarium may be well developed. Tabularium wide with complete or incomplete, distally concave tabulae. There may be an axial notch. There are several rows of highly inclined, rather elongate dissepiments.

Remarks.—The family is restricted to the Middle Devonian and reached its acme in the upper Middle Devonian. Wedekind's genera are here retained since they appear to have some stratigraphic significance. Hill (1942, p. 257) regards the family as a genus, and Wang (1951) as two genera. Also included in this family are the forms described by Wedekind (1925) as the group of *Grypophyllum isactis* (Frech).

Genus STRINGOPHYLLUM Wedekind 1922

Stringophyllum WEDEKIND, 1922*a*, p. 8.

Type species.—By subsequent designation of Wedekind, 1925, p. 64, *S. normale* Wedekind, 1922*a*, p. 9, text-figs. 5,6 on p. 9, from the upper Middle Devonian of Sundwig, Germany.

STRINGOPHYLLUM sp. cf. S. SCHWELMENSE (Wedekind)
Pl. 27, fig. 3; text-fig. 6g

Cf. *Grypophyllum schwelmense* WEDEKIND, 1925, p. 17, pl. 4, figs. 18,19,20.

Small loosely fasciculate *Stringophyllum*. Major septa extend from periphery almost to axis and break up into separated monacanths. Minor septa occur as discontinuous septal crests, in some cases almost completely absent. Bilateral symmetry at axis not very strongly marked. There is a slight tendency to formation of an incipient lonsdaleoid dissepimentarium and to peripheral splitting up of the septa into separate monacanths, but both characteristics are rarely

shown. Diameter of corallite, approximately 16 mms.; number of major septa, 32.

Occurrence.—Five specimens from the north border of Park Corner Copse, near Berry Pomeroy (NGR 20/832628). St-zone.

Remarks.—Wedekind figured specimens of *G. schwelmense* from Paeckelman's collections from the Bergisches Land. The specimens described here differ from these in the disintegration of the major septa at the axis. Wedekind's specimens show a normal bilateral symmetry and the septa do not break up into separate monacanths: he did not mention whether *G. schwelmense* is ever fasciculate.

STRINGOPHYLLUM BATTERSBYI (Edwards & Haime)

Metriophyllum battersbyi EDWARDS & HAIME, 1851, p. 318, and 1835.

Two poor specimens. *Stringophyllum* with very thick major septa, extending from the periphery to the axis: outer wall not preserved. At the axis the septa have a rough bilateral symmetry, but there is also a division of the septa into four quadrants, as is also clearly shown by the holotype. Minor septa much thinner than the major and often incomplete, but they may reach half the length of the major. Major septa rather irregular in thickness. Details of longitudinal section not known.

Occurrence.—One specimen from Shinners Bridge Quarry (NGR 20/789623),? Sp-zone, and one from S.E. of Dartington Hall (NGR 20/832628), high Sp-zone.

Remarks.—Edwards & Haime's illustration is clear: the holotype is now in the British Museum (Natural History). This species of *Stringophyllum* is distinguished from all others by the thickness of its major septa. The holotype is a thin slice, only $\frac{1}{2}$ cm. thick. A part of the outer wall is preserved: it is comparatively thin. The major septa may be beaded, suggesting a tendency to break up into separate monacanths, but separation never takes place in the major septa.

Genus NEOSPONGOPHYLLUM Wedekind 1922

Neospongophyllum WEDEKIND, 1922*a*, p. 10.

Type species.—By subsequent designation of Wedekind, 1925, p. 52, *N. variabile* Wedekind, 1922*a*, p. 12, text-fig. 11 on p. 12, from the "quadrigeminus-zone" of Hand, Bergische-Gladbach, Germany.

Generic description.—Simple or loosely fasciculate subcylindrical to ceratoid corals. Internal structures like *Stringophyllum*, but lonsdaleoid dissepimentarium is present.

NEOSPONGOPHYLLUM SMITHI Taylor Text-fig. 6a

Neospongophyllum smithi TAYLOR, 1950, p. 181, pl. 2, fig. 5.

Occurrence.—One fragment from Old Quarry, Staverton Wood (NGR 20/806636) showing two corallites, one 3 cms. in diameter and one 1.1 cms. in diameter. Poorly preserved. They agree very closely with the holotype.

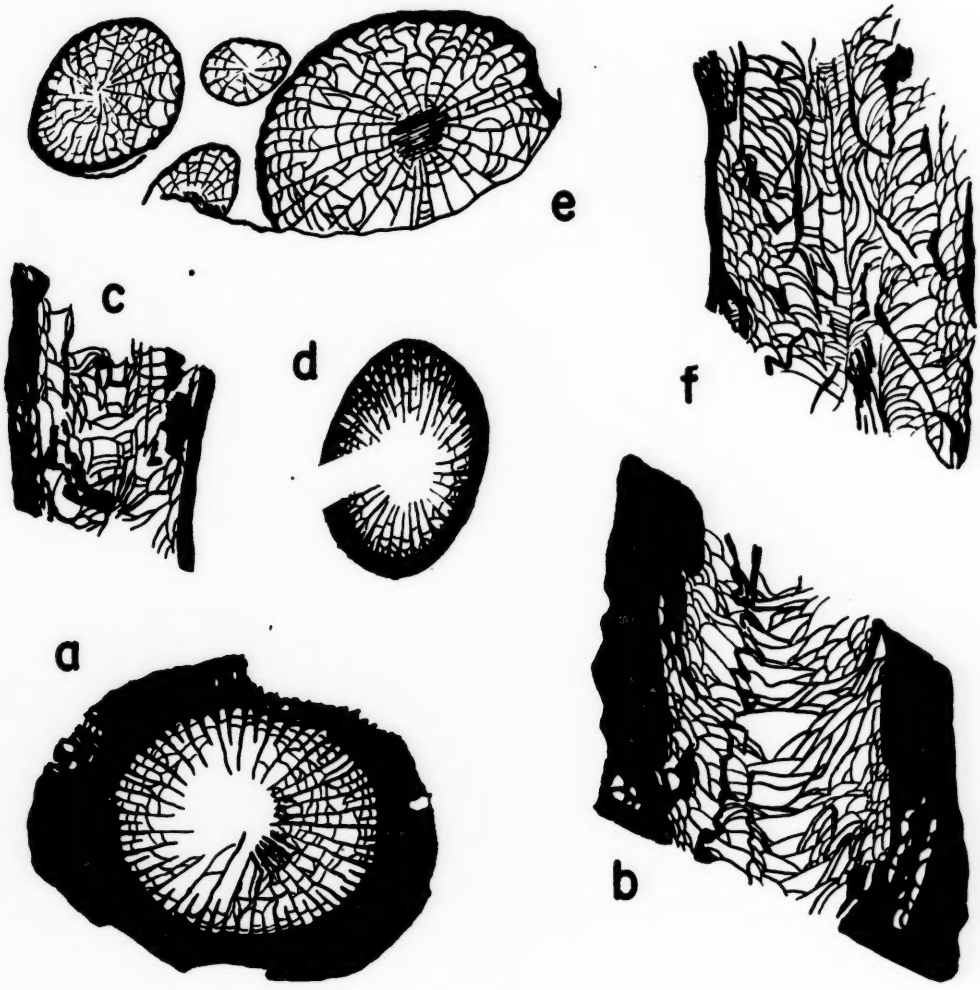
Genus VOLLBRECHTOPHYLLUM Taylor 1950

Schizophyllum WEDEKIND, 1925, p. 59, *non Schizophyllum* VERHOEFF, 1895. *Vollbrechtophyllum* TAYLOR, 1950, p. 182.

Type species.—By original designation *Spongophyllum Büchelense* Schlüter, 1889, p. 321, pl. 7, fig. 8, from the upper Middle Devonian, Bücheler Schichten, Büchel near Bergische-Gladbach, Germany. See also Wedekind 1925, pl. 13, fig. 79 on p. 50 and pl. 12, fig. 71 and 72 on p. 47.

Generic description.—General structure similar to *Stringophyllum*, but major septa split into separate monacanths at the periphery and there is also a tendency towards the formation of a lonsdaleoid dissepimentarium. Minor septa are discontinuous.

Remarks.—In his description Taylor excludes forms with a lonsdaleoid dissepimentarium. His definition of *Vollbrechtophyllum* is therefore not exactly equivalent to Wedekind's definition of *Schizophyllum*, even though the two genera are based on the same species, since Wedekind included forms with a well developed lonsdaleoid dissepimentarium (e.g., *S. tenue* Wedekind 1925, p. 613, pl. 12, fig. 74 and 75 on p. 47). But the type species, as figured by Wedekind, shows signs of a slight development of lonsdaleoid dissepimentarium and hence it does not seem to be possible to exclude forms from this genus even if the character is well developed.



TEXT-FIG. 4

4a,b, Temnophyllum latum Walther, ×2½.
4c,d, Temnophyllum sp., ×1.8.
4e,f, Grypophyllum sp. cf. *G. normale* Wedekind, ×2½.

VOLLBRECHTOPHYLLUM DARTINGTONENSIS, n. sp.
Pl. 27, figs. 4a,4b,5

Large loosely aggregated subcylindrical *Vollbrechtophyllum*. Holotype has a diameter of 3.5 cms. and 61 major septa. The smallest paratype has a diameter of 2 cms. but the number of major septa remains approximately the same as in the holotype. The outer wall is thin. The major septa extend from the periphery, where they may be complete or may split into separate monacanths, to near the axis. The septa are prevented from reaching the axis by the development of a strong axial notch in the numerous tabulae so that a small axial area (diameter about 3 mms.) is free from septa, and in cross-section has the appearance of a pseudoaulos. The minor septa are discontinuous, usually occurring as septal crests. At the periphery there is a tendency to develop lonsdaleoid dissepimentarium but it is never

well developed. The separation of the monacanths of the major septa is also not well developed and only occurs in some of the septa. The tabularium is wide, occupying about half the diameter of the corallite. The tabulae are usually nearly complete, and are distally concave, with a deep axial notch. They are closely crowded, about 15 to 20 tabulae occurring in a vertical distance of one centimeter. The dissepimentarium consists of several rows of rather large elongate dissepiments, inclined steeply towards the axis.

Remarks.—This species is distinguished clearly by the development of the deep axial notch. In other respects the longitudinal section is close to *Stringophyllum normale* Wedekind (1922*a*, p. 9, text-fig. 6: see also 1925, pl. 15, fig. 92). In septal structure *V. dartingtonensis* is intermediate between *S. normale* Wedekind and *V. buechelense* (Schlüter)—cf. Wedekind (1925, p. 59, pl. 12, figs. 71,72). The outer wall is preserved only in one of the paratypes.

Types.—Holotype is specimen 18/10 from the upper beds in Shinner's Bridge Quarry, Dartington (NGR 20/789623): probably Sp-zone (Givetian). Paratypes are specimens 18/9, 18/7, and 18/2 from the same horizon and locality.

VOLLBRECHTOPHYLLUM sp.

Cf. *Stringophyllum kingi* TAYLOR, 1950, p. 179, pl. 2, fig. 8.

Several poorly preserved specimens of *Vollbrechtophyllum*. Major septa tend to split up at the periphery, but as in *V. dartingtonensis* this character is not well developed. In the best preserved specimen the peripheral parts of the septa are thickened. The major septa thin towards the axis where there is a bilateral symmetry: the septal ends are slightly thickened and isolated monacanths may separate at the axis. The minor septa occur only as septal crests or as isolated monacanths, round in cross-section.

Occurrence.—Three specimens from Shinner's Bridge Quarry and one from the north border of Broadbridge Wood near Newton Abbot (NGR 20/837714). All from Sp- or St-zone.

Remarks.—In the peripheral thickening of the septa and in their general structure these forms resemble *Stringophyllum kingi* Taylor, in which, however, the peripheral monacanths of the major septa have not actually separated, though the tendency to separation was described by Taylor. The forms here described are clearly transitional between *Stringophyllum* and *Vollbrechtophyllum*.

Family COLUMNARIIDAE Rominger 1876

For familial description see Stumm (1949, p. 28).

Genus COLUMNARIA Goldfuss 1826

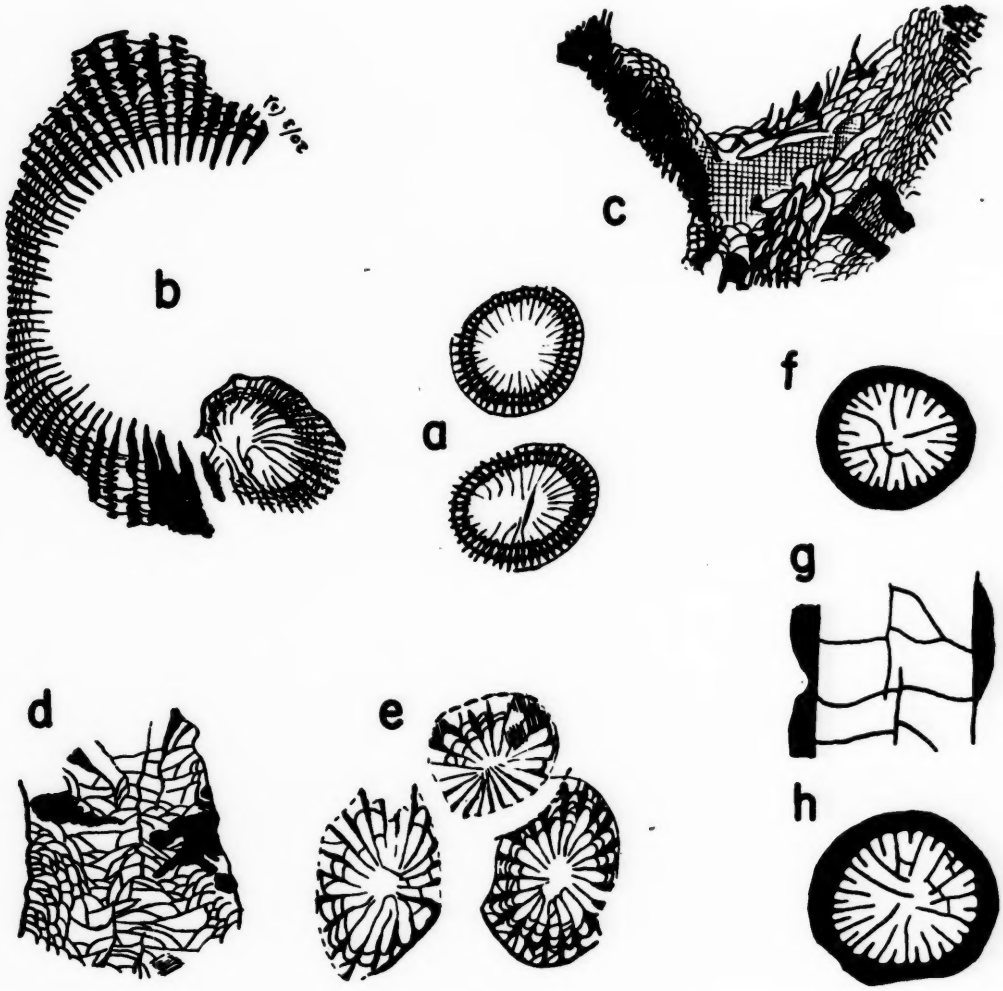
COLUMNARIA RHENANA (Frech)

Pl. 27, figs. 6a,6b,7; text-fig. 5f–h

Cyathophylloides rhenanum FRECH, 1886, p. 93, pl. 3, figs. 1919a.

Fasciculate corals (? in some cases solitary) with a thick outer wall resulting from the thickening of the septa in a peripheral stereozone. Corallites small. Two major septa are commonly longer than the rest and may meet in the center, extending across the corallite. The other major septa are commonly slightly withdrawn from the axis. The minor septa are one third to one half the length of the major septa. The peripheral stereozone may be up to a third of the radius of the corallite, so that in some cases the minor septa are seen only as ridges projecting from the outer wall. The number of septa varies from 20+20 to 16+16: the number of septa on either side of the two longest septa (? cardinal and counter septa) is not equal in all cases, though it is in most cases. The septa are straight, thin and without carinae, and thicken slightly towards the outer wall: they are composed of horizontal, evenly spaced trabeculae. The tabulae are roughly horizontal and are complete: there are about 8 in a vertical distance of 1 cm. Dissepiments are not present. The diameter of the corallite varies from 5 to 10 mms.

Occurrence.—Five specimens from Old Quarry, N.W. of Balland (NGR 20/769714) from the base of the Ashburton limestone (? Dy-zone). Two specimens from West Hill, near East Ogwell (NGR 20/834709)—Sp- or Dy-zone. Three specimens from Emblett Hill (NGR 20/842707) and four



TEXT-FIG. 5

(All ×2½ except as otherwise noted)

5a, Thamnophyllum hoernesi var. *trigemme* (Quenstedt).
5b,c, Heliophyllum shinneri n. sp., holotype.
5d,e, Disphyllum sp.
5f–h, Columnaria rhenana (Frech), ×4.

from the upper beds at Chercombe Bridge (NGR 20/833711)—probably Sp-zone.

Remarks.—The genus *Columnaria* is here given a very broad interpretation. Frech's illustrations of this species show no signs of bilateral symmetry but otherwise the specimens are identical with the holotype. The specimens from Emblett Hill and Chercombe Bridge are apparently solitary whereas the others occur in large fasciculate coralla. The species is widely distributed in S. Devon, being found also in fragments in the Permian breccias near Teignmouth (cf. Geological Survey Collection specimens no.

75729 and 73223). It appears to be a characteristic fossil of the highest parts of the Middle Devonian. The holotype is from the "Schichten mit *Uncites gryphus*" of G. Meyer (1879) at Hand in the Paffrath syncline in Germany, and occurs at about the same horizon as the English specimens (cf. Wedekind 1925, p. 82 *et seq.*). The author has also seen examples of this species from the Canadian North West Territories.

Family DISPHYLLIDAE Hill 1939
Subfamily DISPHYLLINAE
Genus DISPHYLLUM de Fromentel 1861

Disphyllum DE FROMENTEL, 1861, p. 302; LANG & SMITH, 1935, *ex parte;* STUMM, 1949, p. 32.
Schlüteria WEDEKIND, 1922*a*, p. 3.
Megaphyllum SOSHKINA, 1939, p. 14.
Pseudostringophyllum SOSHKINA, 1939, p. 45.

Type species.—By subsequent designation of Lang & Smith, 1934, p. 80, *Cyathophyllum caespitosum* Goldfuss, 1826, p. 60, pl. 19, fig. 26 *only*. Middle Devonian of Eifel, Germany.

Remarks.—For generic description see Stumm *loc. cit.* Since the genus is here considered to be distinct from *Thamnophyllum* (*Phacellophyllum*) it is unnecessary to rename the type species *Disphyllum goldfussi* (Lang and Smith, 1934). If *Pseudostringophyllum* is considered a synonym of *Disphyllum* then a new name is required for *P. caespitosum* Soshkina, 1939, which is not conspecific with *D. caespitosum* (Goldfuss). Lang, Smith & Thomas (1940) regard *Spinophyllum* Wedekind, 1922*a*, as congeneric with *Disphyllum*, but the presence of carinae is here considered to warrant generic status.

DISPHYLLUM CAESPITOSUM (Goldfuss) var.
Text-figs. 3a–g

Cf. *Cyathophyllum caespitosum* GOLDFUSS, 1826, *loc. cit.*
Cf. *Disphyllum goldfussi* LANG & SMITH, 1935, p. 544.

Irregular fasciculate corals. Very similar to *D. caespitosum* but differing in the thickening of the peripheral parts of the septa and dissepiments. The axial ends of the major septa are thin in all cases and are slightly curved, so as to produce a slight axial whorl. The thickening of the septa begins at about their center and increases towards the periphery. The thickening of the dissepiments may give rise to an inner wall, or the peripheral parts may be completely covered in stereoplasm, so that the minor septa only project as ridges from the outer wall. The degree of thickening is variable even within the same corallite. Some specimens are almost free from thickening and are almost identical with the holotype. The number of septa varies from 25-25 to 18-18, and the diameter of the corallite from 0.7 to 1.5 cms.

Occurrence.—Numerous specimens from west of East Ogwell Mill (NGR 20/839708) —probably Frasnian.

DISPHYLLUM sp.
Text-figs. 5d,e

Fasciculate *Disphyllum*. Outer wall thin. Major septa spindle-shaped in cross-section, extending from the periphery almost to the axis. Axial ends thin but septa thicken from the middle to near the periphery where they attenuate slightly. Minor septa are entirely absent: herringbone dissepiments may be poorly developed near the periphery. There are about four rows of inflated dissepiments which are almost horizontal at the periphery but are strongly inclined near the border of the tabularium. There is a periaxial series of tabellae and an axial series of incomplete, slightly distally convex tabulae. There are about 20 major septa and the diameter of the corallite is about 8 mms.

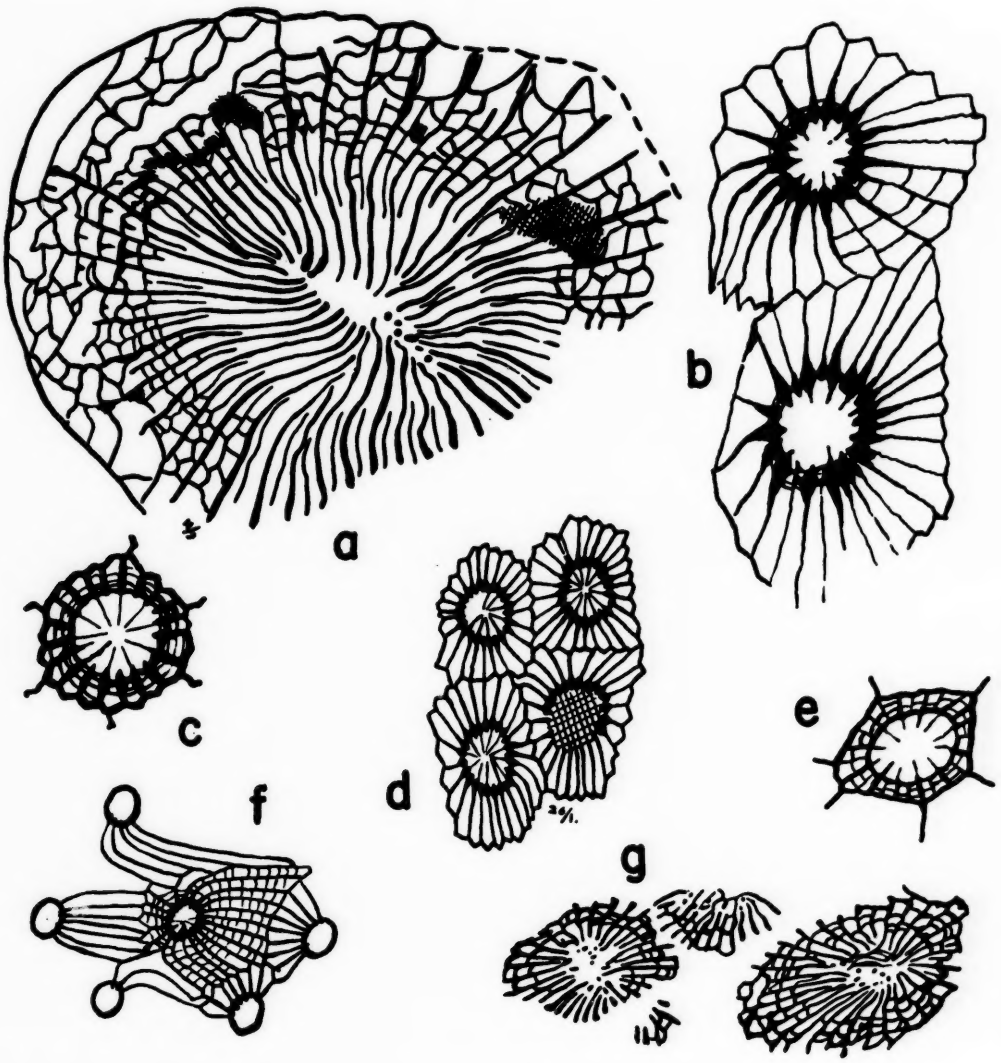
Occurrence.—Fragments of a corallum from a loose boulder in the lane east of Rydon, near Abbotskerswell (NGR 20 /843687).

Remarks.—This species is distinguished by the absence of minor septa and by the slight dilatation of the major septa. However, it has not been found *in situ*. The matrix is a bright brick-red argillaceous limestone and the horizon is probably in the middle or upper Frasnian.

Genus TEMNOPHYLLUM Walther 1928

Temnophyllum WALTHER, 1928, p. 120.

Generic description.—Simple ceratoid corals. Septa of two orders: the major extend to the axis or almost to the axis, the minor are about half as long. Both orders are so dilatated peripherally as to form a wide peripheral stereozone in which the septa are



TEXT-FIG. 6

6a, *Neospongophyllum smithi* Taylor, ×3.
6b, *Phillipsastraea goldfussi* (Edwards & Haime) var.?, ×5.
6c,*6e*, *Phillipsastraea* spp.?, *6c* ×7, *6e* ×8.
6d, *Phillipsastraea goldfussi* (Edwards & Haime) ×4.
6f, *Phillipsastraea pentagona* var. *micrommata* (F. A. Roemer) ×5.
6g, *Stringophyllum* sp. cf. *S. schwelmense* (Wedekind) ×2.

in lateral contact. There are several rows of inclined dissepiments: those near the periphery are usually obscured by the stereozone but where they can be seen they are highly inclined and more inflated than the highly inclined, elongate dissepiments which occur next to the tabularium. There are no horseshoe dissepiments. The tabularium is composed of incomplete tabulae.

Type species.—By subsequent designa-

tion of Lang, Smith & Thomas, 1940, p. 132, *T. latum* Walther from the upper Middle Devonian of Grund, Harz, Germany.

Remarks.—A specimen conspecific with the type species is described below for the first time since the erection of the genus. It is clear that *Temnophyllum* may be distinguished from *Pexiphyllum* Walther 1928 by the absence of horseshoe dissepiments. This was the opinion of Wang (1951, not 1948) and Rozkowska (1953). Rozkowska chose *P. ultimum* Walther as type species of *Pexiphyllum* but this is invalid because of the prior designation of *P. rectum* Walther by Lang, Smith & Thomas (1940, p. 98).

Temnophyllum latum Walther
Text-figs. 4a,b

Temnophyllum latum Walther, 1928, p. 123–124.

The specimen agrees closely with Walther's figure and description, except that it has more septa (62 as against 54). The peripheral stereozone occupies about a third of the radius of the coral. The major septa extend almost to the axis, the minor are half the length of the major. The inner septal ends are thin and smooth but thicken a little towards the stereozone. The septa are composed of trabeculae inclined inwards and upwards at an angle of about 10°–30° to the horizontal. There are no divergent fans. The dissepiments can occasionally be seen within the stereozone, where they are inflated and axially inclined. At the axial border of the dissepimentarium they are elongate and practically vertical. The tabularium consists of incomplete tabulae arranged in a distally concave manner. The diameter is about 2 cms.

Occurrence.—One fragment about two cms. long, from the lower beds, Rugg's Quarry, Ashburton (NGR 20/770712). Probably Dy-zone.

Remarks.—Although there is only a small fragment, it is clear that this is conspecific with the holotype, which is therefore clearly not congeneric with *Pexiphyllum*. The validity of many of Walther's "species" of *Temnophyllum* is doubtful since they are distinguished only on details of the tabularium.

Temnophyllum sp.
Text-figs. 4c,d

Simple subcylindrical *Temnophyllum* with rather poorly developed peripheral stereozone. The major septa withdraw slightly from the axis and thicken gradually towards the periphery. The minor septa are about a third to half as long. Both orders are greatly thickened near the periphery and are in lateral contact in many cases. The dense peripheral stereozone occupies about a fifth of the radius. The dissepimentarium is narrow and is composed of about four rows of highly inclined dissepiments, of which all except the axial row are usually obscured by stereoplasm. The arched tabellae are arranged in a distally concave fashion. There are 30+30 septa and the diameter is about 1.5 cms.

Occurrence.—Two specimens from the hillside east of Dainton Quarry (NGR 20/853660). Upper Middle Devonian.

Temnophyllum sp.

Ceratoid coral. The major septa retreat about a quarter of the radius from the axis. The axial ends are thin but the septa rapidly dilatate towards the periphery. The minor septa are very short, about a third of the length of the major, and are strongly dilatated at the periphery but thin axially. An inner wall is formed by the thickening of the dissepiments, and in parts the entire peripheral zone is filled with stereoplasm so that the minor septa are almost entirely obscured. There are two or three rows of inflated dissepiments, but no true horseshoe dissepiments are present. Tabulae numerous, horizontal, usually complete, about 16–18 in one cm. Diameter about 1.2 cms. There are 29+29 septa.

Occurrence.—One specimen from the highest beds exposed at Chercombe Bridge (NGR 20/833711). ? Sp- or Dy-zone.

Remarks.—The specimen is similar to *T. poshiense* Wang (1948, p. 14, pl. 2, figs. 14–18), but is much simpler in structure and lacks the "narrow peripheral zone of open interseptal loculi." It is clearly related to the simple Disphyllids, and may not be related to the more complex Temnophyllids described by Walther. Wang (1948) has

noted that *Temnophyllum* is probably a form-genus. A specimen from the Ashburton limestone (from NGR 20/769714) is similar but may differ in longitudinal section.

TEMNOPHYLLUM spp.

A large number of specimens from the Ashburton limestone correspond approximately to the group described by Walther (1928), but are too poorly preserved for accurate determination. In general the structure of the horizontal skeletal elements seems to be simpler than in the forms described by Walther.

Genus HELIOPHYLLUM Hall 1846

Heliophyllum HALL, 1846, p. 356.

Type species.—By monotypy *Strombodes helianthoides?* Hall, 1843, p. 209, text-fig. 87, 3 on p. 209 and no. 48, fig. 3 on p. 44 of tables; renamed *Heliophyllum halli* Edwards & Haime, 1850 (p. lxix). Middle Devonian, Hamilton Group, New York.

Generic description.—See Stumm, 1949, p. 21.

Remarks.—Lang, Smith & Thomas (1940) and Stumm (1949) regarded *Keriophyllum* Wedekind 1923 (type species: *K. heiligensteini* Wedekind 1923 p. 34, see also Haller 1935) as synonymous with this genus. Wedekind distinguished between the two genera on the nature of the tabularium, *Heliophyllum* having horizontal or oblique, incomplete tabulae, while *Keriophyllum* has more complex tabularium of Acanthophylloid type. Wang (1948) believed that the carinae were formed in a different manner in the two genera and regarded *Spinophyllum* Wedekind, 1922, as a synonym of *Keriophyllum*. Lang & Smith (1935) regarded *Spinophyllum* as congeneric with *Disphyllum*, to which it is certainly closely related. *Keriophyllum* is here regarded as a subgenus of *Heliophyllum*, and is reserved for forms having a complex development in the dissepimentarium owing to the formation of irregular carinae, alternating on either side of the septum, and owing to the splitting up of the septa peripherally and the formation of lateral dissepiments. *Heliophyllum* might be assigned to the Acanthophyllidae but in view of the general absence of typical Acanthophyllids in America, where *Heliophyllum* is common, it seems unlikely that it belongs to this group.

HELIOPHYLLUM SHINNERI, n. sp.
Text-figs. 5b,c

The holotype is a specimen embedded in dark crinoidal limestone: several serial sections have been made. Trochoid corals with a deep calice. Septa numerous (over 70) and radially arranged. The major septa reach the axis and in the early stages the axial ends may be slightly dilatated and fused together. The minor septa are about two-thirds as long. At the border of the dissepimentarium the septa dilatate and thin gradually towards the axis, but towards the periphery they become thin and highly carinate. In one of the paratypes there is an inner wall formed by the lateral contact of the dilatated parts of the septa, but this is not found in the other specimens. On the peripheral parts of the septa the carinae are of typical cross-bar type, though they may be oblique to the septal plane (perhaps as a result of subsequent deformation of the specimens). Alternating carinae are rare. There is a tendency to the formation of a reticulate structure owing to the formation of lateral dissepiments but there is no true splitting of the septa. The carinae are thickened in many cases so that the structure is not clear.

In the holotype peripheral increase may observed. In the earliest stages the septa are thin and reach to the center where the axial ends become fused together and somewhat thickened, forming a pseudo-columella, which remains during the whole period of growth observed, though perhaps not to maturity (there is no pseudo-columella in one of the paratypes). Those parts of the daughter corallite which are axially placed in respect of the parent (the neotissue) remain underdeveloped and the septa do not have well-developed carinae.

Types.—Holotype is specimen 20/3 (slides 1–6) from the beds above the shale band in Shinner's Bridge Quarry. (NGR 20/789623). Paratype 21/5 is from the lower beds at the

same quarry, and paratype 6/2 is from N.E. of Newpark Hill Plantation, Littlehempston (NGR 20/822630). All probably from the St-zone.

Remarks.—This species is close to *H. halli* Edwards & Haime, and *H. dahlense* (Wedekind) but in neither of these forms do the septa remain much dilatated in the mature stages.

Genus PHILLIPSASTRAEA d'Orbigny 1849

Phillipsastrea D'ORBIGNY, 1849, p. 12.

Type species.—By subsequent designation of Edwards & Haime, 1850, p. lxxi, *Astrea hennahi* Lonsdale *partim* 1840, p. 697, pl. 58, figs. 3,3a,3b, from the highest Middle Devonian, Barton, Torquay, South Devon. See Smith (1917).

Generic description.—See Stumm (1949, p. 34) and Rozkowska (1953).

Remarks.—Wang (1951) included *Phillipsastraea* in the Phacellophyllinae (= Pachyphyllinae) on account of its assymmetrical fans of trabeculae. However, the genus has no horseshoe dissepiments and the trabeculae never actually dip towards the axis, so that Stumm and Rozkowska place the genus in the Disphyllinae. Walther (1928) was mistaken in believing that the entry of *Phillipsastraea* marks the beginning of the Upper Devonian, since in Devon the entry may occur as low as the upper Sp-zone.

PHILLIPSASTRAEA HENNAHI (Lonsdale)

Astrea hennahi LONSDALE, 1840, p. 697, pl. 58, figs. 3,3a,3b.
Phillipsastraea hennahi SMITH, 1917, p. 284–289, pl. 22, figs. 1–4.

Occurrence.—One specimen from the Quarry east of Dartington Hall (NGR 20/803627) and one from S.E. of Dartington Hall (NGR 20/801625): probably upper Sp-zone.

PHILLIPSASTRAEA GOLDFUSSI (Edwards & Haime)
Text-fig. 6d

Acervularia Goldfussi EDWARDS & HAIME, 1853, p. 236, pl. 53, figs. 3,3a.
Phillipsastraea pentagona FRECH, 1885, p. 55, *ex parte.*
Phillipsastraea goldfussi ROZKOWSKA, 1953, p. 62, figs. 35,36,37, and pl. 8, figs. 5,6.

Occurrence. –One specimen from the road cutting south of Ransley Quarry (NGR 20/844702) and several from the Quarry itself. Probably middle or upper Frasnian.

Remarks —Rozkowska (1953) has shown that in her assemblages the two species *P. goldfussi* and *P. pentagona* are distinguished from each other by the number of septa and by the diameter of the tabularium. Although there is a wide variation, the frequency curves show distinct maxima for the two species.

There is a large quantity of material from Ransley Quarry in the collections in the British Museum (Natural History), and in the Museum of the Geological Survey. Until a variation study has been made of this material it is difficult to evaluate the large number of "species" that have been described. The following may be only varieties of this species:

Acervularia coronata EDWARDS & HAIME, 1853, op. cit., p. 237, pl. 53, figs. 4,4a,4b.
Acervularia limitata EDWARDS & HAIME, 1853, op. cit., p. 238, pl. 54, fig. 1.
Acervularia Roemeri DE VERNEUIL & HAIME, Edwards & Haime, 1853, op. cit., p. 239, pl. 54, fig. 3.

PHILLIPSASTRAEA GOLDFUSSI Edwards & Haime, var.?
Text-fig. 6b

Similar to *P. goldfussi* but differing from it in size. The diameter of the tabularium is 2.5 mms. and that of the corallite 8 mms. The carination is also slightly stronger than in *P. goldfussi.* There are 24 septa.

Occurrence.—Several fragments (probably of the same corallum) from the road south of Ransley Quarry.

Remarks.—Rozkowska examined numerous specimens from Poland and stated that the diameter of the tabularium varies from 1.2 to 2.8 mms. with the maximum number of specimens measuring 1.8 mms.

PHILLIPSASTRAEA PENTAGONA (Goldfuss) var. MICROMMATA (F. Roemer)
Text-fig. 6f

Phillipsastraea pentagona (Goldfuss) var. *micrommata* (F. Roemer) FRECH, 1885, pp. 56–57, pl.

3, figs. 11–13, pl. 8, fig. 1, *ex parte;* ROZKOWSKA, 1953, p. 66, figs. 36–38, pl. 8, fig. 8.

Phillipsastraea with subplocoid colonies. Septa about 20 in number, sinuous in shape in the dissepimentarium, with feeble carinae. Diameter of the tabularium about 3.5–4.0 mms. Inner wall well developed owing to dilatation of the septa at the border of the tabularium. The minor septa do not continue into the tabularium but the major septa extend in a very attenuated form almost to the axis.

Occurrence.—Two specimens from Ransley Quarry. According to Rozkowska, this variety is characteristic of the upper Frasnian.

PHILLIPSASTRAEA spp.?
Text-fig. 6c,e

Two small fragments. Their main features are as follows:

	Usual no. of septa	Diam. tabularium	Diam. corallite
27/1	22	1.0–1.2 mms.	3–4 mms.
26/4	24	1.0 mms.	2.0 mms.

In 27/1 (text-fig. 6c) the septa are rather strongly dilatated, even in their peripheral parts. In 26/4 there is little septal dilatation and the septa are not in contact with each other. Both forms may be varieties of *P. goldfussi*, which they also resemble in longitudinal section.

Subfamily PACHYPHYLLINAE
Genus THAMNOPHYLLUM Penecke 1894

Fascicularia DYBOWSKI, 1873, p. 336, *non Fascicularia* Lamarck, 1816, p. 220.
Thamnophyllum PENECKE, 1894, p. 593.
Phacelophyllum GURICH, 1909, p. 102.
Peneckiella SOSHKINA, 1939, p. 23.

Type species.—By subsequent designation of Lang & Smith (1935, p. 564), *T. stachei* Penecke (1894, op. cit., p. 594, pl. 8, figs. 1–3, pl. 11, figs. 1,2): from the Lower and lower Middle Devonian of Graz, Austria.

Generic description.—Phaceloid corals with with a thin epitheca. The major septa retreat somewhat from the axis and may be amplexoid, the minor septa are short. The symmetry is radial: the septa may be thickened by stereoplasm, but are non-carinate. There is a peripheral zone of horizontal dissepiments between the epitheca and a single row of horseshoe-dissepiments marking the border of the tabularium. An inner wall may be formed by dilatation in the zone of horseshoe-dissepiments. There may be a periaxial series of inclined tabellae: the tabulae are usually horizontal and complete.

Remarks.—Von Schouppé (1949) has shown that variability in thickening with stereoplasm characterizes this genus, and in *Disphyllum* (a closely related genus) this also the case, as demonstrated above. Hence there is no valid reason for separating *Phacellophyllum* from *Thamnophyllum.*

THAMNOPHYLLUM HOERNESI (Penecke) var. TRIGEMME (Quenstedt)
Text-fig. 5a

Cyathophyllum caespitosum trigemme QUENSTEDT, 1879, p. 518, Tabb. 162, figs. 5–8.
Disphyllum{Phacellophyllum}trigemme LANG & SMITH, 1935, p. 575, text-figs. 30,31.
Macgeea (Thamnophyllum) hörnesi (Penecke) var. *trigemme* (Quenstedt) VON SCHOUPPE, 1949, p. 131, figs. 5,6,8,9,17,17a,29.

Occurrence.—Three specimens from Shinner's Bridge Quarry (NGR 20/789623), one from Emblett Hill (NGR 20/842707), and three from the north border of Broadridge Wood (NGR 20/837714): Givetian.

Remarks.—For a review of this species see von Schouppé (1949). Von Schouppé showed in a study of material from the St. Gotthard massif in the Alps, that the amount of stereoplasmic thickening is variable, so that *T. trigemme* must be considered as only a variety of *T. hoernesi.* All the author's specimens from Devonshire occur as (?) simple or small fasciculate colonies, consisting of two or three corallites only.

THAMNOPHYLLUM CAESPITOSUM (Goldfuss) var. MINUS (Roemer)

Diphyphyllum minus F. A. ROEMER, 1855, p. 29, pl. 6, figs. 12a,12b,12c.
Disphyllum {Phacellophyllum}minus LANG & SMITH, 1935, p. 576, pl. 35, fig. 3.
Macgeea (Thamnophyllum) caespitosum var. *minus* VON SCHOUPPE, 1949, p. 156.

One fragment of a phaceloid corallum from Loventor Copse, near Berry Pomeroy

(NGR 20/846632): St-zone. The specimen is somewhat dolomitized so that the structures are not very well preserved. The selective dolomitization gives an appearance of stereoplasmic thickening which is, in fact, not present. There are about 30 septa: the major are long and somewhat withdrawn from the axis; the minor are about half as long. All the septa are thin. There is an outer series of horizontal dissepiments and an inner series of horseshoe-dissepiments. There is an axial series of nearly horizontal, complete tabulae and a periaxial series of small, inclined tabellae. The diameter of the corallite is about 3 to 4 mms.

Remarks.—Von Schouppé has established that this variety differs from *T. caespitosum* (Goldfuss) only in size. Lang & Smith believed that only horseshoe-dissepiments are developed but von Schouppé has shown that this is not so; and the peripheral series of dissepiments is visible in the specimen described here. *T. caespitosum* always has a diameter of 6 mms. or more: some of the forms listed by Lang & Smith as synonymous belong, according to von Schouppé, to the smaller variety. *T. caespitosum* differs from *T. hoernesi* var. *trigemme* in having less septa and in the more frequent occurrence of stereoplasmic thickening in *T. hoernesi.*

REFERENCES

Butler, A. J., 1935, The use of cellulose films in Paleontology: Nature, v. 135, no. 3413, p. 510.

Champernowne, A., 1878, Notes on some Devonian stromatoporoids from Dartington, near Totnes: Quart. Jour. Geol. Soc. London, v. 35, p. 67–68.

——, 1881, The Ashburton Limestone: its age and relations: Geol. Mag., p. 410–416.

——, 1884, On some Zaphrentoid corals from British Devonian beds: Quart. Jour. Geol. Soc. London, v. 40, p. 497–506, pls. 21–23.

Davidson, T. A., 1864, 1865, A monograph of the British Devonian Brachiopoda. Parts I and II: Monogr. Palaeont. Soc. London.

De Fromentel, E., 1858–1861, Introduction a a l'etude des polypiers fossiles. Paris. 357 p.

D'Orbigny, A., 1849, Note sur les polypiers fossiles. Paris. 12p.

Duncan, P. M., 1868, On the Genera *Heterophyllia, Battersbyia, Palaeocyclus* and *Asterosmilia;* the anatomy of their species, etc.: Philos. Trans. Roy. Soc. London, v. 157, p. 643–656, pl. 31–23.

Dybowski, W. N., 1873–1874, Monographie der Zoantharia sclerodermata rugosa aus der Silurformation Estlands, Nord-Liv-lands und der Insel Gotland; Archiv. Naturkunde Liv-, Ehst- und Kurlands, v. 5, 1873, p. 257–414, pls. 1,2; 1874, p. 415–532, pls. 3–5.

Edwards, H. M., & Haime, J., 1850, A Monograph of the British Fossil Corals Pt. I Introduction, etc.: Monogr. Palaeont. Soc. London, cxxxv+71 p., 11 pls.

——, 1851, Monographie des Polypiers fossiles des Terrains Palaeozoiques; Archiv. Mus. Hist. Nat. Paris, v. 5, 502 p., 20 pls.

——, 1853, A Monograph of the British Fossil Corals, Pt. IV, Corals from the Devonian Formation: p. 211–244, pls. 47–56, Monogr. Palaeont. Soc. London.

Frech, F., 1885, Die Korallenfauna des Oberdevons in Deutchland; Zeitschr. deutsch. geol. Gesell., v. 37, p. 21–130, pls. 1–11.

——, 1886, Die Cyathophyllidae und Zaphrentidae des deutschen Mitteldevon: Palaeont. Abh. v. 3, p. 117–233, pls. 13–22.

Goldfuss, G. A., 1826, Petrefacta Germaniae I: Düsseldorf, 76 pp., 25 pls.

Gurich, G., 1909, Leitfossilien; II Devon; p. 97–199, pls. 29–52, Berlin.

Hall, J., 1943, Natural History of New York Pt. IV, Geology of New York, Pt. IV: Albany, xxii+683 p., 21 pls.

——, 1846, in Dana, J. D., Zoophytes *in* United States Exploring Expedition during the years 1838–1842 . . .; x+740 p. and Atlas (61 pls.).

Haller, W., 1935, Einige Biostratigraphische Untersuchungen in der Rohrer Mulde unter besondered Berücksichtigung der Keriophyllen: Jahrbuch Preuss. Geol. Landesanst, v. 56, p. 590–632, pls. 32–43.

Hill, D., 1936, The British Silurian Rugose Corals and their acanthine septa: Philos. Trans. Roy. Soc. London, ser. B, v. 226, p. 189–217, pls. 29,30.

——, 1939a, The Devonian rugose corals of Lilydale and Loyola, Victoria: Proc. Roy. Soc. Victoria, n. ser., v. 51, p. 219–256; pls. 13–16.

——, 1939b, The Middle Devonian rugose corals of Queensland, I Douglas Creek and Drummond Creek, Clermont District: Proc. Roy. Soc. Queensland, v. 50, p. 55–65, pls. 4–5.

——, 1942, The Middle Devonian rugose corals of Queensland, III Burdekin Downs, Flamming River and Reid Gap, north Queensland: Proc. Roy. Soc. Queensland, v. 53, p. 229–268, pls. 5–11.

——, 1956, Rugosa, *in* Moore, R. C. (ed.), Treatise on Invertebrate Paleontology, Part F: Coelenterata, p. F233–F323.

Kettnerova, M., 1932, Palaeontological studies in the Devonian of Celechovice (Moravia), Part IV, Rugosa: Travaux Inst. Géol. Paléont. Univ. Charles, Prague, 97 p., 5 pls.

Krömmelbein, K., Hotz, E., Kräusel, W., & Struve, W., 1955, Zur Geologie der Eifelkalk-

mulden: Beiheft zum Geologischen Jahrbuch, Heft. 17, Hannover, 204 p.

LANG, W. D., & SMITH, S., 1934, Ludwig's "Corallen aus Paläolithischen Formation" and the genotype of *Disphyllum* de Fromentel: Annals Mag. Nat. History, ser. 10, v. 13, p. 78–81.

——, 1935, *Cyathophyllum caespitosum* Goldf. and other Devonian Corals considered in a revision of that species: Quart. Jour. Geol. Soc. London, v. 91, p. 538–590, pls. 35–37.

LANG, W. D., SMITH, S., & THOMAS, H. D., 1940, Index of Palaeozoic coral genera: Pub. Brit. Mus. (Nat. History), London, 231 p.

LECOMPTE, M., 1952, Madréporaires paléozoiques: *in* Piveteau J. (ed.) Traité de Paléontologie, v. 1, p. 419–538.

——, 1956, Quelques précisions sur le phenomène récifal dans le Devonian de l'Ardenne et sur le rythme sedimentaire dans lequel il s'intègre: Inst. Roy. Sci. Nat. Belgique, Bull., Tome XXXII, no. 21, 39 p., 2 pls.

LONSDALE, W., 1840, Notes on the age of the limestones of South Devonshire: Trans. Geol. Soc. London, ser. 2, v. 5, pt. 3, p. 721.

MAURER, F., 1885, Die Fauna der Kalke von Waldgirmes bei Giessen; Abh. Geol. Landes. Hessen Darmstadt, v. 1, no. 2, p. 61–340, with Atlas.

MCCOY, F., 1850, Description of three new Devonian Zoophytes: Annals Mag. Nat. History, ser. 2, v. 7, p. 377–378.

——, 1851–1855, *in* SEDGWICK A., A synopsis of the classification of the British Palaeozoic Rocks: London and Cambridge.

MEYER, G., 1879, Der mitteldevonische Kalk von Paffrath: Dissertation, Bonn. 75 p.

NICHOLSON, H. A., 1886–1892, A monograph of British Stromatoporoids: Monogr. Palaeont. Soc. London.

PENECKE, K. A., 1894, Das Grazer Devon: Jahrbuch K. Geol. Reichsanst., v. 43, pts. 3–4, p. 567–616, pls. 7–12.

PHILLIPS, J., 1841, Figures and descriptions of the Palaeozoic fossils of Cornwall, Devon and West Somerset: Geol. Survey Great Britain and Ireland, London, xii+231 p., 60 pl.

QUENSTEDT, F. A., 1879, Petrefaktenkunde Deutschlands. VI, Die Röhren und Sternkorallen; p. 145–624, Leipzig.

RICHTER, R., 1952, Exkursion in die Prümer Mulde (Eifel): Zeitschr. deutsch. geol. Gesell, v. 103, p. 343–352.

ROEMER, F. A., 1855, Beiträge zur geologischen Kenntnis des nordwestlichen Harzgebirges. Dritte Abteilung; Palaeontographica, v. 5, iv+44 p., 8 pls.

ROZKOWSKA, M. D., 1953, Pachyphyllinae et *Phillipsastraea* du Frasnien de Polognes: Palaeontologica Polonica, v. 5, 89 p., 8 pls.

SANFORD, W. G., 1939, A review of the families of tetracorals: America Jour. Sci., v. 237, p. 295–323, 401–423.

SCHINDEWOLF, O. H., 1941, Zur Kenntnis der Heterophylliden, einer eigentümlichen Paläozoischen Korallengruppe: Palëont. Zeitschr., v. 22, p. 277–283.

SCHLÜTER, C., 1889, Anthozoen des rheinischen Mitteldevon: Abh. geol. Specialkarte Preuss. Thüring. Staat., v. 8, no. 4, p. i–x, 259–465, 16 pls.

SCHMIDT, W. E., 1936, Die Schichtenfolge des Devons bei Soetenich in die Eifel: Jahrbuch Preuss. Geol. Landesanst, v. 56, p. 292–323.

SMITH, S., 1917, *Aulina rotiformis* gen. et sp. nov., *Phillipsastraea hennahi* (Lonsdale) and *Orionastraea* gen. nov.: Quart. Jour. Geol. Soc. London, v. 72, p. 280–307, pls. 22–24.

SOSHKINA, E. D., 1936, Les Coraux Rugosa du Devonien moyen de l'Oural du Nord: Trans. Polar Comm. Acad. Sci. U.S.S.R., v. 28, p. 15–76.

——, 1939, Verchnedevonskie korally Rugosa Urala: Trudy Paleont. Inst. U.S.S.R., v. 94 p. 1–88.

——, 1951, Pozdnedevonskie korally Rugosa ich sistematika i evoljucija: Trudy Paleont. Inst. U.S.S.R., v. 34, p. 1–122.

STUMM, E. C., 1949, Revision of the families and genera of the Devonian tetracorals: Mem. Geol. Soc. America, no. 40, viii+92 pp., 25 pls.

TAYLOR, P. W., 1950, The Plymouth Limestone; and the Devonian tetracorals of the Plymouth Limestone: Trans. Roy. Geol. Soc. Cornwall, v. 18, pt. 2, p. 146–160,161–214, pls. 1–5.

——, 1952, Unpublished thesis for Ph.D.: Cambridge University.

VOLLBRECHT, E., 1922, Uber den Bau von *Cosmophyllum* nov. gen.: Sitzungsber. Gesell. Beförd. gesamten Naturw. Marburg (1921) pt. 1, p. 17–34.

——, 1926, Die Digonphyllinae aus dem unteren Mittel-Devon der Eifel: Neues Jahrbuch Min. Geol. Paläont., v. 55B, p. 189–273, pls. 8–16.

VON SCHOUPPÉ, A., 1949, Die "Thamnophyllen" und ihre Beziehung zur Gruppe des "*Cyathophyllum caespitosum*": Palaeontographica, v. 97A, p. 99–180.

WALTHER, C., 1928, Untersuchungen über die Mitteldevon—Oberdevongrenze: Zeitschr. deutch. geol. Gesell., v. 80, p. 97–152.

WANG, H. C., 1948, The middle Devonian rugose corals of eastern Yunnan: Peking Natl. Univ. Geol. Inst., Pub. 33, 46 p., 5 pls.

——, 1951, A revision of the Zoantharia Rugosa in the light of their minute skeletal structures: Philos. Trans. Roy. Soc., London, ser. B, v. 234, p. 175–246, pls. 4–9.

WEDEKIND, R., 1922*a*, Zur Kenntnis der Stringophyllen des oberen Mitteldevon: Sitzungsber. Gesell. Beförd. gesamten Naturw. Marburg (1921), pt. 1, p. 1–16.

——, 1922*b*, Beiträge zur Kenntnis der Mesophyllen: Palaeont. Zeitschr., v. 4, p. 48–63, pls. 1,2.

——, 1923, Die Gliederung des Mitteldevons auf Grund von Korallen: Sitzungsber. Gesell.

Beförd. gesamten Naturw. Marburg (1922), pt. 1, p. 24–35.

——, 1924–1925, Das Mitteldevon der Eifel. Part I, 91 p.; Part II, 85 p.: Schriften Gesell. zur Beförd. gesamten. Naturw. Marburg, v. 14.

——, 1934, Kritische Bermerkungen zur Gliederung des Eifeler Mitteldevons: Zeitschr. deutsch. geol. Gesell., v. 86, p. 19–28.

——, 1937, Einführung in die Grundlagen der Historischen Geologie, II Band, Mikrobiostratigraphie: die Korallen- und Foraminiferenzeit. Stuttgart. 136 p.

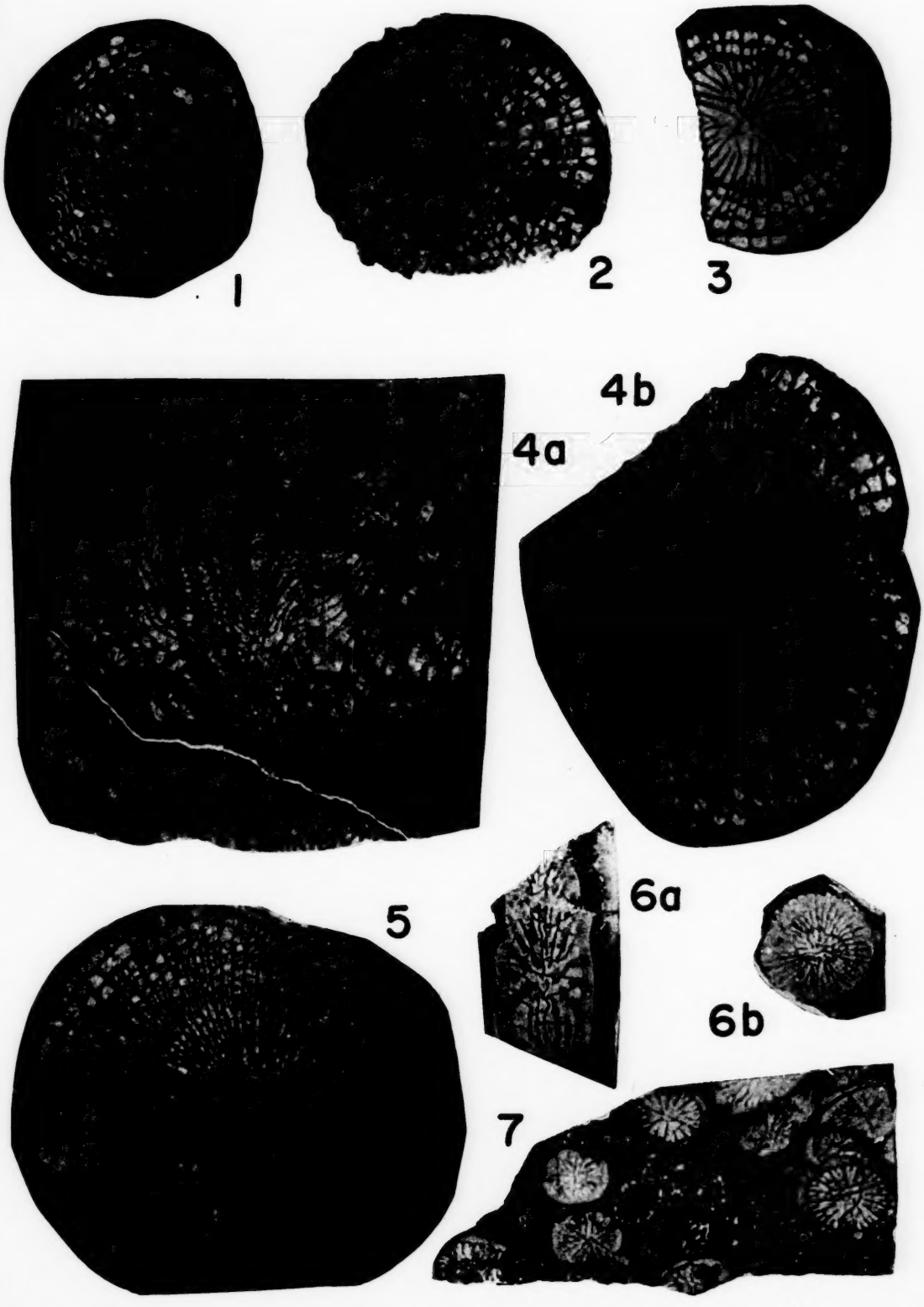
——, & VOLLBRECHT, E. 1931–1932, Die Lytophyllidae des mittleren Mitteldevon des Eifel: Palaeontographica, v. 75, pts. 3–6, p. 81–110, pls. 15–46, 1931; v. 76, pts. 4–6, p. 95–120, pls. 9–14, 1932.

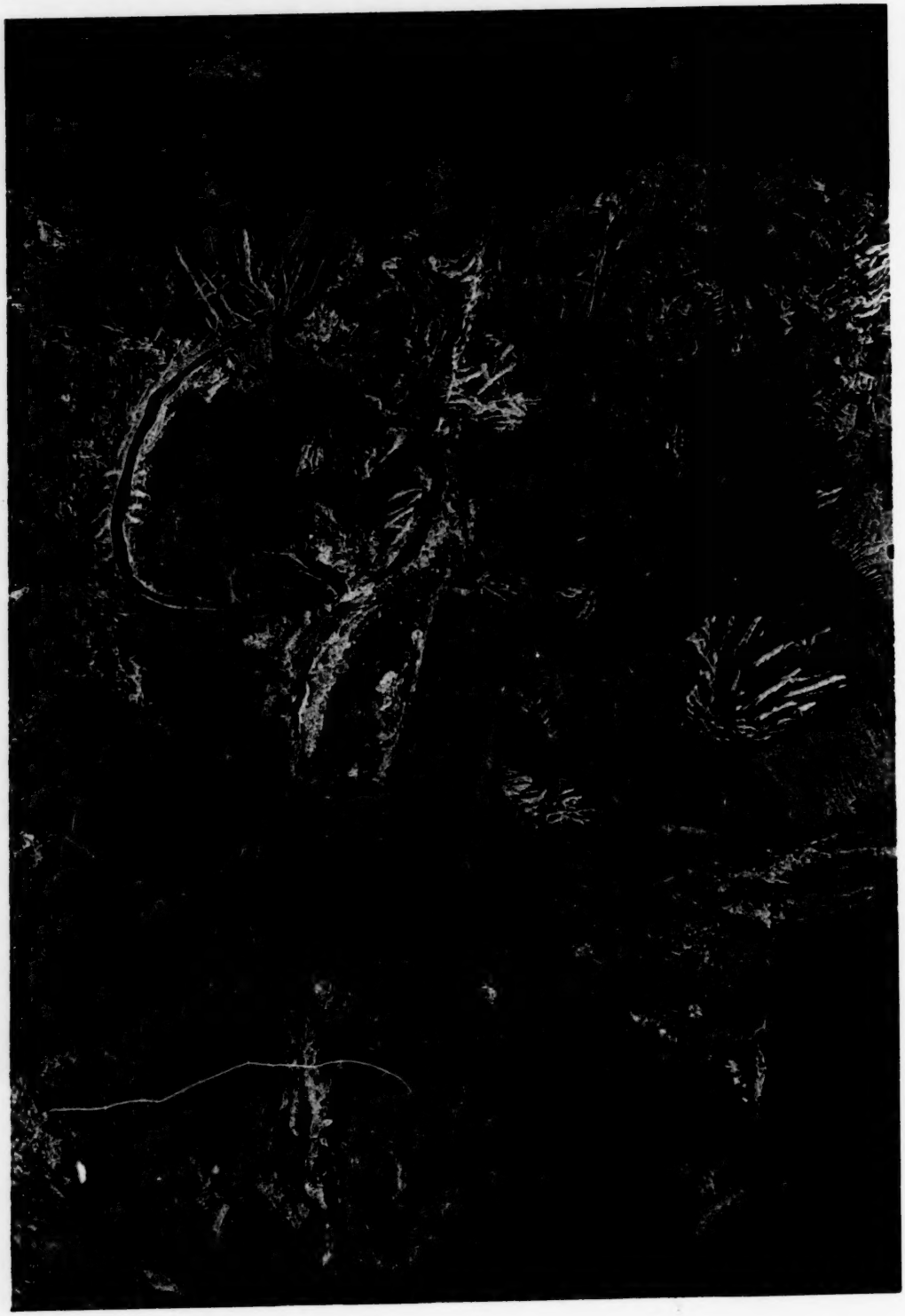
WHIDBORNE, G. F., 1889–1907, The Devonian fauna of the South of England. Volume 1, The fauna of the limestone of Lummaton, Wolborough, Chercombe Bridge and Chudleigh (1889–1892); Volume 2 (1892–1907): Monogr. Palaeont. Soc. London.

MANUSCRIPT RECEIVED OCTOBER 22, 1957.

EXPLANATION OF PLATE 27

FIGS. *1,2—Grypophyllum tenue* Wedekind, ×1.5
3—Stringophyllum sp. cf. *S. schwelmense* Wedekind, ×1.5
4a,4b,5—Vollbrechtophyllum dartingtonensis sp. nov.; *4a,b*, holotype; *5*, paratype no. 18/9. ×1.5
6a,b,7—Columnaria rhenana (Frech) from NE. of Balland; *7*, intergrowth with *Amphipora ramosa* Phillips, ×1.5


1
2
3
4a
4b
5
6a
6b
7



JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 161–178, PL. 28, 5 TEXT-FIGS., JANUARY 1959

ACROPLOUS VORAX, A NEW AND UNUSUAL LABYRINTHODONT AMPHIBIAN FROM THE KANSAS PERMIAN

NICHOLAS HOTTON III
Department of Anatomy, University of Kansas, Lawrence, Kansas

ABSTRACT.—An excellently preserved trimerorhachoid amphibian from the middle Wolfcamp of Kansas is described, and is made the type of a new genus *Acroplous*, as *A. vorax*, n. sp. In both its morphology and its temporal occurrence the animal serves as a link between the Pennsylvanian genera *Pelion* and *Saurerpeton* and the Permian genera *Eobrachyops* and *Trimerorhachis*. Certain fossil amphibian remains from the Appalachian region, described as *Saurerpeton obtusum*, are referred to *Acroplous*.

Position of external nares and shape of skull afford room for conjecture about the habits of *Acroplous*. Its geological occurrence is discussed and compared with that of its Texas contemporaries.

INTRODUCTION

A HITHERTO undescribed specimen of fossil labyrinthodont, number 9822 in the paleontological collection of the University of Kansas Museum of Natural History, recovered from Permian strata near Keats, Riley County, Kansas, has been found to contribute extensively to three different facets of knowledge of late Paleozoic amphibian life. The specimen is well-preserved and reasonably complete, and provides information concerning morphology and relationships of the taxonomic group to which it belongs. The discovery in Kansas of a well-preserved fossil amphibian of late Paleozoic age is valuable in itself, partly because of the extreme rarity of such finds, and partly because the beds in which this specimen was found are correlated with Texas sediments that contain a much better-known Permian fauna. As is shown in the body of this paper, the amphibian under study is related to at least one and probably two well-understood animals found in strata of similar age in Texas. Finally, certain unusual adaptive features of the Kansas animal raise questions concerning phylogenetic trends within lines of late Paleozoic and early Mesozoic amphibians.

The writer wishes to express his appreciation to several of his colleagues at the University of Kansas for their cooperation: to Professor E. Raymond Hall, Director of the Museum of Natural History, for the free use of museum facilities; to Professor R. W. Wilson, for the loan of the specimen under study; and to Professor Frank E. Peabody, formerly of the Zoology Department, for introducing the writer to specimen number 9822. Thanks are also due to Dr. E. H. Colbert, of the American Museum of Natural History, for the loan of a cast of the type specimen of *Eobrachyops townendi* Watson. Professor L. R. Lind, of the Department of Latin and Greek, University of Kansas, provided invaluable aid in naming the beast.

GEOLOGY

Local Stratigraphy

The site from which the fossil was recovered is located in Riley County, Kansas, just east of the village of Keats, in the east-central part of section 36, township 9 south, range 6 east. The locality is a west-facing cut-bank of an intermittent stream and lies about 100 yards north of U. S. Highway 24. Most of the surface of Riley County is underlain by rocks of Wolfcamp age; the Geologic Map of Riley and Geary Counties,

EXPLANATION OF PLATE 28

Acroplous vorax, n. gen., n. sp. Holotype, Pal. Col. KU MNH 9822. ×1.75.

Kansas (Jewett, 1941) from which the map coordinates were taken, shows the line of outcrop of the Council Grove group as a northwestward re-entrant into the collecting locality due to the removal of the overlying Chase group along the course of the intermittent stream.

The bed of the stream at this point consists of a slabby limestone of crystalline texture and dark gray color, referable to the Funston formation. Above the Funston lies the Speiser shale, the uppermost formation in the Council Grove group (Moore, et al., 1951); it is exposed at the Keats locality in characteristic fashion. Its lowest portion consists of about 15 feet of varicolored shale. The lower shale is red in its middle part and grades to gray-green at top and bottom; it weathers out in small blocks and is exposed for 50 or 60 feet along the stream. The middle part of the Speiser appears as a layer of impure, grainy limestone less than a foot thick, that contains a few poorly-preserved fossils; it is overlain by the upper shale phase, a buff-gray, platey shale about $2\frac{1}{2}$ feet thick that is very fossiliferous (Derbyia, ?*Composita*). The next higher lithologic unit exposed at the cut-bank consists of a massive, light-colored, cherty limestone at least 7 feet thick, the Threemile member of the Wreford formation (Chase group). The ledge formed by the Threemile supports the steep valley wall for more than a mile northwestward from the cut-bank, providing exposure of the upper two layers of the Speiser shale over the entire distance (cf. Jewett, 1941, and Moore, et al., 1951).

The specimen at hand is reported to have come from the lower gray-green band (about five feet thick at the Keats locality) of the variegated-shale phase of the Speiser. The matrix in which the specimen is preserved consists of calcareous clay, more gray than green in color; it is massive and structureless, and shows conchoidal fracture.

Correlation

In Kansas the Wolfcamp series is divided by Moore into three groups of generally marine sediments. The Council Grove, to which the Speiser formation belongs, is the middle of these three groups. In the vertebrate-bearing region of north-central Texas the Wolfcamp is generally believed to be represented by the upper part of the Cisco series (Pueblo formation), and by the Wichita series (Moran, Putnam, and Admiral formations) (Adams, et al., 1939; Dott, 1941). The upper Cisco and Wichita sediments are terrestrial in nature, containing only a few thin marine limestones, and stratigraphic opinion is divided on precise correlation of parts of the terrestrial series with parts of the marine Wolfcamp. Romer (1935) uses the Kansas Cottonwood limestone, in the middle Council Grove, as a convenient marker, and suggests a direct correlation between it and the Coleman Junction limestone of Texas, which lies between the Putnam and Admiral formations. A similar correlation is implied by Schuchert (1935). Adams' correlation may place the Cottonwood slightly above this level, and Dott's slightly below it. The Speiser formation, at the top of the Council Grove, may correspond to a level somewhere between the upper part of the Putnam and the upper part of the Admiral, according to these correlations.

On the other hand, Thompson (1954), basing his conclusions on fusulinid faunae, suggests direct correlation between lower Council Grove (Kansas section from Hughes Creek shale to Neva limestone) and middle Pueblo (Texas section from Waldrip No. 3 limestone to Camp Creek shale). In addition, he suggests correlation of the middle Chase (Florence limestone) with the middle Moran Gouldbusk limestone), and thus brackets the Speiser quite closely to the top of the Pueblo. Thompson's correlations place the Speiser at the lowest vertebrate-bearing levels of the Texas section, and differ from those of the earlier papers by nearly the whole thickness of the Wichita group. Although material in the present study does not contribute directly to resolution of this difference of opinion, the morphological affinities of *Acroplous* lie as much with *Pelion* and *Saurerpeton* of the Linton, Ohio coal fauna (Upper Freeport), as with *Eobrachyops* (Watson, 1956) of the Arroyo of Texas. In view of this fact, placement of the Speiser at a Pueblo level rather than at an Admiral or Putnam level may perhaps be favored.

Paleogeography

Strata of Wolfcamp age exposed in the collecting localities of Archer and Baylor Counties, Texas, consist of about 600 or 700 feet of variegated shales and sandstones, separated at intervals by thin layers of limestone, which in the terrestrial facies of the Wolfcamp are almost the only practical formation boundary-markers. In the lower Wichita beds the limestones are poorly developed and of limited extent. The clastic deposits become thinner and less sandy to the south, finally grading into typically marine limestones and shales (Romer, 1935).

The accepted interpretation of these thick terrestrial sediments, with their crossbedding, sandstone and fine conglomerate channels, and other evidences of stream deposition, is that they represent an extensive delta on the eastern shore of the midcontinental Permo-Carboniferous sea. The delta was subject to occasional marine transgressions of short duration. A large part of the clastic material must have been derived, at least during Wichita time, from higher land in southeastern Oklahoma, that was raised originally as part of the Arbuckle uplift. This orogeny culminated in the Upper Pennsylvanian (pre-Virgil; see Moore, 1935, but cf. King, 1942), and the highlands resulting from it were thoroughly subdued by erosion by Wolfcamp time. Nevertheless it is probable that the Arbuckle Mountains area remained topographically positive until the end of Leonard time.

Kansas rocks of Wolfcamp age consist of more than 700 feet of interbedded limestones and shales, a large part of which has been interpreted by Jewett (1933) as a series of cyclothems, recording alternate transgressions and withdrawals of the sea. According to Hattin (1957), the variegated lower portion of the Speiser represents an interval of subaerial deposition that marks the beginning of the Wreford megacyclothem. In Kansas, the outcrop of the Speiser trends almost due north-south, from Marshal County at the Nebraska state line to Cowley County at the Oklahoma line. Over the northern two-thirds of this distance it is of fairly constant thickness, ranging from 12 to 15 feet, but in the southern third of its exposure it becomes much thicker, reaching a maximum of nearly 40 feet in Cowley County. Most of the increase in thickness occurs in the lower variegated-shale phase, and in Cowley County it is accompanied by local development of fine-grained channel sandstones in the lower shale. Hattin interprets the evidence of the Kansas section as indication that

> "—one is dealing with the sediments of a low-lying near-shore plain upon which sands, silt, and clay were being deposited by slowly shifting sluggish streams."

He suggests further that the streams approached from an easterly or southeasterly direction, and that the nearest high ground lay to the south or southeast, in an area that was "tectonically active throughout much of Pennsylvanian and Permian time."

A comparison of the terrestrial component of the Speiser shale with its stratigraphic equivalent in the Wolfcamp of northcentral Texas indicates that both the Kansas and Texas clastics probably had a common source area in the higher lands of southeastern Oklahoma. The fact that terrestrial deposits make up only a small part of the Kansas Wolfcamp, while in Archer and Baylor Counties they comprise nearly the whole Wolfcamp section, means that the Texas collecting area lies nearer to the source of supply, and probably was a little higher during Wolfcamp time. Kansas is far enough away from the source area that terrestrial sediments were laid down in the Wolfcamp only during marine regressions of relatively great areal extent and of considerable duration. Although the Speiser shale becomes thinner northward, it continues as a layer of terrestrial origin for a much greater distance from the southeast Oklahoma "highlands" than does its Texas equivalent. From this one may assume that it had easterly sources of supply as well as its source in Oklahoma. In contrast to the distribution of the Speiser, terrestrial deposits of the Texas Wolfcamp grade rapidly into marine facies to the south, indicating that they are more directly dependent upon the Oklahoma source for their clastics.

The variegated-shale phase of the Speiser formation can be interpreted as marking the eastern shore of the Permo-Carbonifer-

ous midcontinental sea at a point in time (middle Wolfcamp). The north-south trend of the shoreline was interrupted in Oklahoma by a peninsula trending at right angles to it, the backbone of which was provided by higher ground resulting from uplifts related to the Wichita-Arbuckle orogeny. The northern and southern flanks of the peninsula were deltaic in nature. The thickened and channeled exposures of the Speiser in Cowley County, Kansas, represent marginal deposits of the delta on the north side of the peninsula close to its base, and grade northward into thinner, finer-grained, but still terrestrial beds referable to on-shore facies of a strand-line. The thicker and in part coarser red clastics in Baylor and Archer Counties, Texas, represent deposits laid down at the same time, well within the delta on the south flank of the peninsula, much closer to the source of the sediments. The Texas sediments lie further west than the Speiser shale, and thus further seaward along the peninsula; for this reason they grade southward into typical marine deposits rather than into strand-line deposits as the Speiser does. The lack of any very coarse sediments or unstable minerals in either the Kansas or Texas deposits indicates that the source areas of both were of low elevation and slight relief.

SYSTEMATIC DESCRIPTION

Class AMPHIBIA
Order TEMNOSPONDYLI
Suborder RHACHITOMI
Family TRIMERORHACHIDAE

ACROPLOUS,[1] n. gen.

Diagnosis.—A short-faced labyrinthodont amphibian, the skull of which closely resembles the skull of *Eobrachyops townendi* Watson in general shape, dermal pattern, occiput, and palate. Differs from *Eobrachyops* in the following respects; small but distinct otic notch present; quadrate located well anterior to occiput; snout deeper and nares larger and more dorsally-placed; symphyseal tusks developed on lower jaw, and openings present in anterior palate to receive them; dermal elements of midline series narrow, orbits close together; parietal lengthened at the expense of both frontal and postparietal, supratemporal very large. Tabular reduced, separated from border of otic notch by posterolateral process of supratemporal. Vertebrae protorhachitomous; intercentra incomplete rings, open at top, wedge-shaped in lateral aspect; pleurocentra paired, large; tips of pleurocentral elements visible in ventral view of some segments, although never joined together ventrally (text-fig. 5,B). Neural arch components poorly developed. Dermal pectoral girdle broad, flat, heavily sculptured; clavicles not in contact anteriorly. Interclavicle roughly five-sided, bluntly pointed posteriorly; anterior margin deeply pectinate (text-fig. 3,B). Limbs large, feet spreading, digits long, terminal phalanges slender and lizard-like; bones poorly ossified, tarsals and carpals unossified.

ACROPLOUS VORAX,[2] n. sp.
Pl. 28; text-figs. 1–5

Type.—KUMNH No. 9822. Nearly complete but partially disarticulated skull, fragmentary lower jaw. Two articulated sets of central axial elements of about six segments apiece, scattered central and neural arch elements. Disarticulated dermal pectoral elements, a fragment composed of ilium and ischium, and abundant but scattered limb elements. Small bony plates and thin, scalelike integumental structures.

Horizon and locality.—Within the lowest 5 feet of the Speiser formation, middle Wolfcamp, just east of Keats, Riley County, Kansas, in the east-central part of section 36, township 9 south, range 6 east. Approximately 100 yards north of U. S. Highway 24.

Diagnosis.—Same as for genus.

PRESERVATION AND RESTORATION

The skull was crushed flat after death, so that the cheek region now lies in the same plane as the skull table. A large crack, probably the result of this crushing, runs from the anterior end of the otic notch to the

[1] From ἀκρόπλοος (acroplous), swimming at the top. The name is intended to carry the implication of "surface cruiser," and is based upon probable habits inferred from the position of the external nares and the depth of the back of the skull.

[2] Specific designation refers to the supposed voracity of the animal, inferred from its large symphyseal and palatine tusks, and from the gape of its jaws.

posterior margin of the orbit. Most of the dermal elements of the left side have been destroyed, apparently before burial, exposing the marginal bones of the palate and the greater part of the parasphenoid. The left pterygoid has been drifted out of position and now lies in back of the left side of the skull. The right pterygoid is covered by the well-preserved dermal bones of the right side of the skull. The dorsal side of the snout is badly weathered, but enough remains to permit determination of the posterior margin of the naris, and of the tip of the snout. Dorsally the occipital region is well preserved.

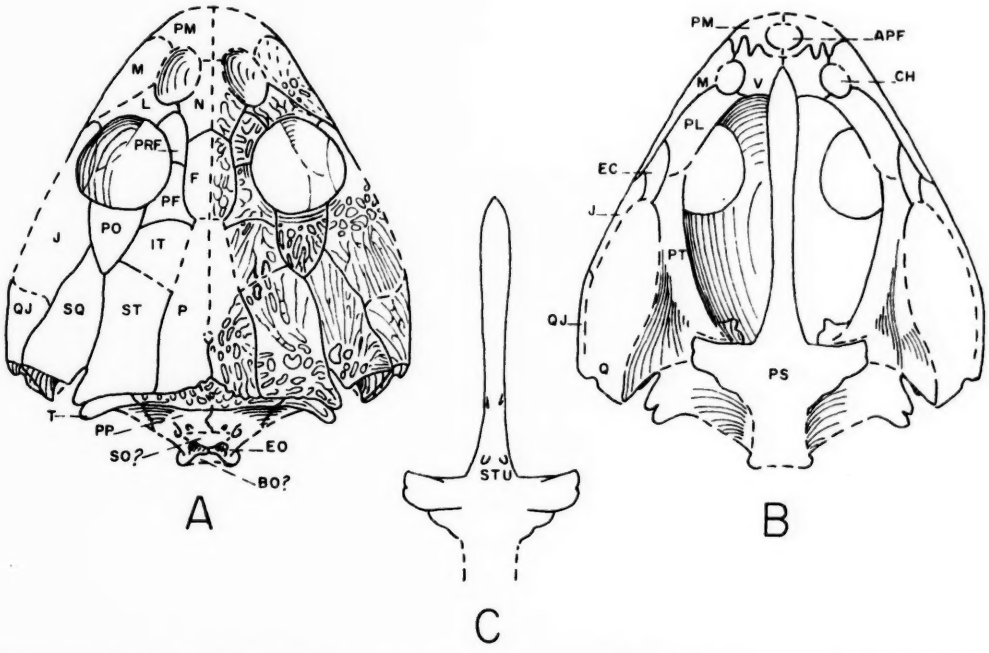
Because of post-mortem changes, the depth of the skull in the cheek region is not immediately apparent in the specimen as preserved. Restoration of the pterygoid to its true relationships to other bones was accomplished by making scale drawings of the parts in question on 1 mm. coordinate paper, and arranging the pieces until they fitted properly. The position of the pterygoid as restored maintains consistent relationships with the marginal bones of the palate, with the cheek region, and with the quadrate, and the characteristic depth of the cheek may be accepted with confidence. The only other parts of the skull that required restoration were the pre-choanal region of the palate and the lateral margin of the maxilla; only slight changes in position were needed.

MORPHOLOGY

Skull roof

(text-fig. 1,A)

In dorsal aspect the skull presents a distinctive appearance, with its large, anteriorly-placed orbits, slit-like otic notches, and posteriorly-slanting occiput. Behind the orbit each dermal bone is ornamented by a pattern of ridges and grooves radiating from an area of more or less circular pits. In front of the orbit and along the occipital margin the bones show only pits, without



TEXT-FIG. *1*.—Skull of *Acroplous vorax*, n. gen., n. sp., restored, ×1.5. A, dorsal aspect. B, palatal aspect. C, dorsal aspect of parasphenoid. Reference letters: APF, anterior palatine fenestra; BO, basioccipital; CH, choana; EC, ectopterygoid; EO, exoccipital; F, frontal; IT, intertemporal; J, jugal; L, lacrimal; M, maxilla; N, nasal; P, parietal; PF, postfrontal; PL, palatine; PM, premaxilla; PO, postorbital; PP, postparietal; PRF, prefrontal; PS, parasphenoid; PT, pterygoid; Q, quadrate; QJ, quadratojugal; SO, supraoccipital; SQ, squamosal; ST, supratemporal; STU, sella turcica; T, tabular; V, vomer.

any radial markings. Lateral line grooves are restricted to half-circles around the posterior and medial margins of the orbits, much as in *Eobrachyops*. Table 1 presents measurements of certain salient dimensions of the skull. Diagrams in this paper represent the restored skull as projected normal to the plane of the diagram, and other measurements may be obtained from them on this basis.

TABLE 1—MEASUREMENTS (IN MM.) OF DERMAL ROOF OF SKULL

Longitudinal	
Top of foramen magnum to snout	44
"Occipital crest" of postparietal to snout	40
"Occipital crest" of postparietal to pineal opening	7
"Occipital crest" of postparietal to posterior margin of orbit	20
"Occipital crest" of postparietal to posterior margin of external naris	30
Transverse	
Greatest width (6 mm. anterior to pineal opening)	42
Width at quadrate	40
Width of table (between anterior tips of otic notches)	28
Interorbital distance	8
Miscellaneous	
Longitudinal diameter of orbit	8–9
Transverse diameter of orbit	9–10
Maximum depth of skull ("occipital crest" to ventroposterior angle of quadrato-jugal)	20

Although an intertemporal bone is present, the dermal pattern should perhaps be spoken of as conservative rather than primitive, for it has adjusted to the peculiarities of skull shape in characteristic fashion. The intertemporal is fairly large, but appears dwarfed by the greatly expanded supratemporal. The subcutaneous portion of tabular is reduced to a small splint of bone lying transversely behind supratemporal. It is cut off from contact with the otic notch by a projection of the posterolateral corner of supratemporal. Like the tabular, the subcutaneous portion of postparietal is much reduced, and together with tabular forms a narrow, upstanding ridge that borders the occipital margin of the skull table, here termed the "occipital crest." A greater part of postparietal covers the smooth dorsal surface of the occiput, to which a ventral flange of tabular also contributes. The parietal bone is about twice as long as the frontal, and both are peculiarly narrow. They look as though their area had been encroached upon, the area of the parietal by the supratemporal and that of the frontal by the enlarged orbits. In spite of the narrowness of the interorbital region, the frontal does not contribute to the orbital margin, and the circumorbital series of bones is complete.

Shortening of the snout is accompanied by absolute enlargement of the external nares in *Acroplous*, with the result that the bones of the snout are reduced in size and "crowded" in appearance. All of the snout bones are present except septomaxilla, and all are of about the same size, the nasal having become proportionately reduced. Lacrimal has a broad contact with both the orbit and external naris, but no particular phylogenetic significance need be attached to this fact. Indeed, with reduction of snout and enlargement of nares, space between orbit and naris has been so curtailed that even the prefrontal comes very close to actual contact with the external naris. The posterior margin of external naris lies within 2 mm. of the anterior margin of the orbit, and the medial margin lies within 2 mm. of the midline at its closest approach. The large nares thus lie close together on top of the snout, just in front of the eyes, in rather frog-like fashion. The extreme dorsal position of the nares suggests that they functioned periscopically (or more properly, snorkel-like) in *Acroplous*, in a manner similar to the nares of a bullfrog basking at the surface of its pond.

The bones of the cheek form a broad, gently convex shield, the posterior margin of which describes a slight forward curve from otic notch to quadrate (text-fig. 2,A). Squamosal and jugal have sutural contact with supratemporal and postorbital respectively, and, restored to its proper relationships with quadrate and pterygoid, the cheek shield slants downward from the skull table at an angle of about 60 degrees (text-fig. 2,B). An anterior process of jugal is reconstructed as extending forward to form the inferior margin of the orbit. Posteriorly, squamosal and quadrato-jugal are produced

medialward to form a thin flange on the posterior surface of the skull. This flange probably made contact with a laterally-directed flange of the quadrate ramus of pterygoid to enclose the persistently cartilagenous quadrate posteriorly, as in *Eobrachyops*. The medial margin of quadrato-jugal bears a distinct notch, which may mark the lateral border of the paraquadrate (quadrate) foramen seen in some labyrinthodonts and many reptiles.

The distinctive shape of the dermal skull of *Acroplous* is not due solely to shortening of the snout relative to the postorbital region, but also includes absolute enlargement of the postorbital region accompanied by deepening of the cheek. The elongation and enlargement of parietal, intertemporal, supratemporal, postorbital, squamosal, jugal, and quadrato-jugal, contrasted to the "compressed" appearance of postparietal and tabular, points to a "zone of expansion" bounded in front by the orbits and behind by the bones bordering the occiput. Sculpture of the expanded bones is predominantly of the radiating ridge-and-groove pattern, and if one accepts the premise that areas of radiate sculpture represent areas of greatest post-embryonic growth, one is forced to conclude that most of the post-embryonic growth of the skull has taken place in this region.

Amphibian skulls in which the preorbital moiety is much shorter than the postorbital are often said to be of "larval" or "primitive" shape, but this concept should not be applied without consideration of the pattern of dermal bones. In truly primitive or larval forms, one may expect the nasal to be appreciably larger than the other narial or circumorbital elements, and postparietal and tabular to be of fair size also. In spite of the general shape of the skull, the dermal pattern of *Acroplous* fulfills neither of these criteria, and so is neither primitive nor larval. The specimen at hand may, however, represent a young individual, for some of the dermal elements of the skull are rather loosely connected by lap-joints rather than by fully-developed sutures.

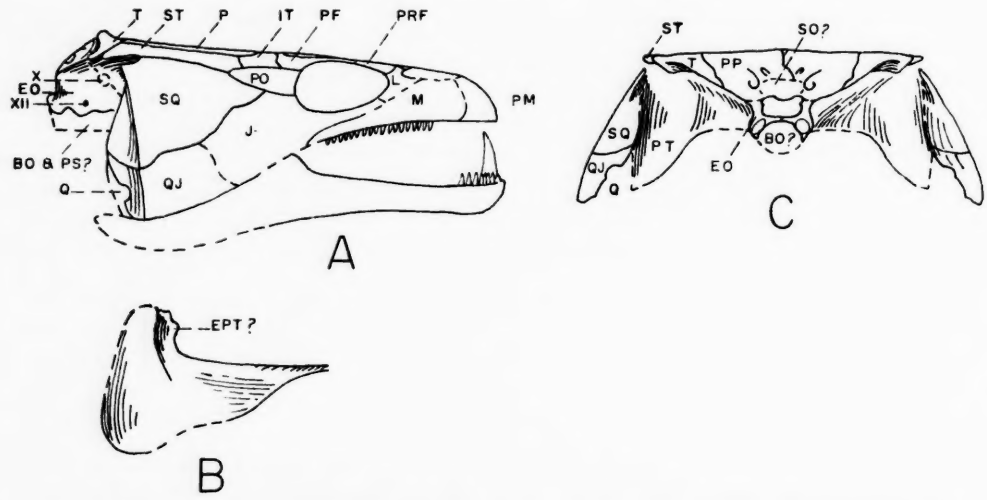
Acroplous is smaller than *Eobrachyops*, being about half as large as *E. townendi* (Watson, 1956) and about two-thirds as large as *E. casei* (Broili, 1913; Watson, 1956). Smaller size, skull shape, degree of ossification, and the forward position of the quadrate may prompt the suggestion that *Acroplous* represents an immature individual of *Eobrachyops*, and that its small otic notch is rudimentary and would have closed up with further growth. However, in degree of ossification and condition of lateral line grooves, available examples of *Acroplous* and *Eobrachyops* appear to have been at a comparable developmental age at death, and expansion of the postorbital skull bones had already produced in the former a pattern that is distinct from that of *Eobrachyops*, irrespective of the presence or absence of the otic notch. These facts obviate the possibility that further growth would have increased the similarity between *Acroplous* and *Eobrachyops*. It is very probable that characters of *Acroplous* that might be interpreted as "larval" do not indicate an actual larval condition but are neotenic in nature, and that the specimen at hand represents a definitive adult condition.

Occiput

(text-fig. 1,A; text-fig. 2,A and C)

The occiput projects backward about 6 mm. behind the posterior margin of the skull table, and is covered dorsally by a ventroposteriorly-directed flange of postparietal and tabular bones. A sinuous midline suture separates the two postparietals, but disappears about 2 mm. above the upper margin of the broad, low foramen magnum. Absence of a notch in the dorsal margin of foramen magnum, into which the midline suture might run, suggests the presence of an ossified supraoccipital bone. No other sutures are visible around the foramen magnum, and no interpretation of the two foramina in the postparietal is hazarded. Laterally the dorsal occipital surface tapers to a thin ridge on the back of tabular. The posttemporal fenestra consists of the space between this ridge and a ventral process of the tabular in front of it. The ventral tabular process probably made contact with a cartilagenous paroccipital process, which was covered dorsally and posteriorly by the occipital flange of postparietal and tabular.

Flanking foramen magnum, the exoccipitals are thickened and columnar in appearance. Ventrally and medially, the col-



TEXT-FIG. 2.—Skull of *A. vorax*, restored, ×1.5. A, lateral aspect; anterior marginal teeth and palatine teeth in upper jaw, and posterior teeth in lower jaw not shown. B, right pterygoid in lateral aspect. C, occipital aspect. Reference letters: EPT, epipterygoid; X, vagal foramen; XII, hypoglossal foramen; others as in text-fig. 1.

umnar part of each bone is expanded into a thin pediment that meets its fellow of the opposite side to form the floor of foramen magnum. The occipital condyle appears to be double, each half consisting of a thickened posterior projection from the base of the exoccipital. This may be merely an accident of preservation, however, due to poor ossification of basioccipital. Basioccipital shows a broad posterior surface, and may have been built up in cartilage to contribute to a functionally single occipital condyle. Cranial nerve XII exits via a canal that passes through the exoccipital pediment, entering the bone a short distance inside the foramen magnum, and leaving it just in front of the base of the condyle. Anterior to its columnar portion, the exoccipital passes forward as a vertical bony lamina, the dorsal margin of which makes extensive contact with the ventral surface of the occipital flange of postparietal. The front of the lamina curves slightly laterally, presumably to ensheath the back of the unossified otic capsule. The anterior margin of exoccipital is badly preserved and was further damaged in preparation, so that its actual position is not known with certainty. The broken line in text-fig. 2,A represents merely the most posterior location possible for it. The vagal foramen shown in text-fig. 2,A is also tentatively located, by means of vague indications found among the debris of the anterior margin during preparation. The vertical lamina of exoccipital is continued below the level of the condylar part of the bone to ensheath, at least partially, the poorly-ossified basioccipital.

Palate
(text-fig. 1,B)

All bones of the left side of the palate except pterygoid are exposed as a result of natural removal of the dermal bones of the skull roof. Parasphenoid (text-fig. 1,C) is a very flat, sword-shaped bone, whose cultriform process comprises about three-quarters of its length of 34 mm. The wings of parasphenoid measure about 18 mm. from tip to tip, and their nearly straight anterior margins are oriented at right angles to the long axis of the bone. The region of greatest thickness, at the base of the cultriform process, must include a contribution from the basisphenoid, for it bears a shallow depression, the sella turcica, on its dorsal surface. Two foramina of about .5 mm. diameter flank the sella turcica, and about 5 mm. in front of then lies another pair of tiny, slit-like openings. The appreciable size of the

posterior openings suggests that they admitted internal carotid arteries, which then divided into ophthalmic and cerebral carotid arteries within the braincase, as described by Francis (1934) in *Salamandra*. The small anterior foramina may indicate nutrient branches coming from the cerebral carotid artieries as they ran forward on the ventral surface of the brain. The body of parasphenoid is thin-edged posteriorly and laterally, and underlies the basioccipital posteriorly to within about 2.5 mm. of the occipital condyles.

The middle part of pterygoid is preserved with its medial surface buried in matrix, but enough of the region is exposed to show an internal process of moderate size. The lateral half of the anterior margin of parasphenoid wing is turned ventrally as a flange about 1 mm. deep, to form an anteriorly-directed surface for articulation with the internal process of pterygoid. In this respect the basipterygoid joint resembles that of forms like *Trimerorhachis* or *Eobrachyops*. However, the parasphenoid contribution to the joint is much thinner in *Acroplous* than in those forms. Accordingly, either the articulation must have been weaker in *Acroplous*, or it had additional surface made up by a persistently cartilagenous basipterygoid process dorsal to the parasphenoid wing. The dorsal surface of the wing is marked by transverse ridges in the proper position for contact with such a process.

The internal process of pterygoid lies just below a stout epipterygoid about 5 mm. high. On the right side of the skull, where the dermal elements have been crushed down onto the palate, the position of epipterygoid is marked by a hump in the supratemporal, which helps to orient the internal process with respect to the parasphenoid wing and basipterygoid process.

Some unusual features of the pterygoid (text-fig. 2,B) result from the characteristic depth of cheek and anterior position of quadrate in *Acroplous*. Quadrate lies only about 6 mm. behind the basipterygoid process about 8 mm. below it, so that the sheet-like quadrate ramus slants outward and sharply downward, little backward prolongation being necessary. Its posterodorsal margin rises to meet the medial flange of squamosal and quadratojugal behind the quadrate, passes medially in contact with the ventral surface of squamosal and supratemporal in front of the otic notch, and grades into the otic process of pterygoid just behind the epipterygoid. Thus a posterodorsal lamina from the quadrate ramus encloses the subtemporal fossa posteriorly. The palatine ramus of pterygoid curves slightly laterally as it passes forward to make contact with ectopterygoid and palatine, midway along the lateral orbital margin. Its medial border, together with the concave medial border of palatine, form the lateral margin of the large interpterygoid vacuity. The ventral surface of palatine ramus is covered by a shagreen of small denticles. The posterior two-thirds of its lateral margin is produced ventrally as a vertical flange; passing backward below the epipterygoid, the flange begins to slant laterally and grades insensibly into the quadrate ramus. The vertical flange is almost as deep as the cheek and forms a medial wall for the subtemporal fossa, intervening in life between the trigeminal muscles and the buccal cavity.

Ectopterygoid and palatine bones are flat, and show strong dorsal reinforcement along their lateral contact with the maxilla. The small ectopterygoid is in contact with the buttressed anterior edge of jugal, medially with the palatine ramus of pterygoid, and anteriorly with the palatine. Palatine is elongate and curves in an antero-medial direction. Its anterior margin is excavated as the posterior rim of the internal naris, and it appears to have a short contact with the vomer just medial to the choana. The vomer has a firm union with the anterior end of the cultriform process. Its postero-lateral corner is deeply excavated to form most of the margin of the choana, and anteriorly the bone exhibits a deeply serrrate suture with premaxilla. Maxilla and premaxilla bear sharp, conical marginal teeth about 1 mm. in length. Ventrally, premaxilla is confined to the anterior tip of the snout; its dorsal extent is unknown. Maxilla extends from about 3 mm. behind the end of the snout to the level of the posterior margin of the orbit; marginal teeth are present throughout its length. A sheet of sculptured bone rises well onto the dorsum of the antorbital part of the skull to make contact with lacrimal and jugal. The medial margin of each premaxilla

is deeply notched just behind the marginal tooth-row, the two notches together forming a socket about 2 mm. long and 4 mm. wide, for the reception of a large symphyseal tusk, described below. A broken labyrinthine tooth of the same size and shape as the symphyseal tusk lies in the matrix near the skull, and the reinforcement of the marginal palatine bones suggests that they all bear large teeth.

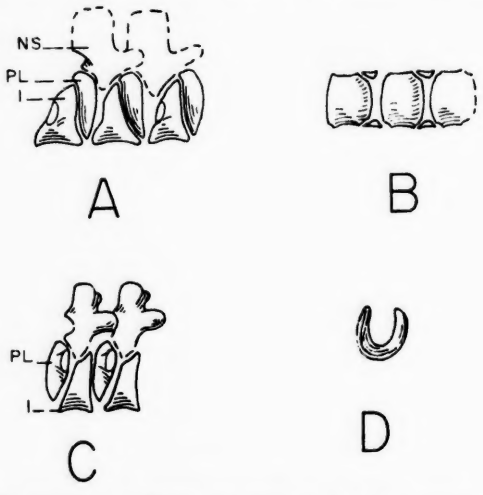
The muzzle of *Acroplous* is restored as considerably deeper than the extremely shallow muzzle of *Eobrachyops* chiefly because of the presence of symphyseal tusks. The tusks are long enough to have passed through the dorsal dermal bones when the mouth was closed, if the snout were no deeper than that of *Eobrachyops*. The median anterior fenestra permits passage of the tusks through the palatine portion of the premaxillae, but unfortunately the dorsal snout bones are missing, so that presence or absence of an equivalent opening in that layer cannot be determined. The large nares may have been prolonged anteriorly to receive the tips of the tusks, but in that case they must have reached nearly to the anterior margin of the skull, and must needs have been nearly or quite confluent anteriorly, a most unlikely arrangement. Alternatively, the snout must have been deep enough to accommodate the tusks without their passing through the dorsal bones; this interpretation is supported by the vertical antorbital flange of maxilla.

Lower Jaw
(text-fig. 2,A)

The anterior end of the left lower jaw is well-preserved, exposed in medial aspect. It is between 3 and 4 mm. deep at the symphysis, and its transverse cross-section diameter is only slightly less than that. At the symphysis stands a sharp, slightly recurved, labyrinthine tusk about 6 mm. in height. Immediately behind and lateral to it, on the dorsal surface of the jaw, is a slight concavity of about the same diameter as the base of the tusk, presumably for reception of the point of its vomerine counterpart. Just lateral to the symphyseal tusk and its accompanying pit, seven small marginal teeth are preserved that are similar in all respects to the maxillary teeth. Preservation of the remainder of the jaw is poor, largely because of the destruction of most of the lateral dermal elements. A large meckel's cartilage was present, and the remaining bones, those of the medial wall of the meckelian space, are thin and badly fractured. Their suture pattern is indeterminable. Enough is preserved, however, to indicate the following features. There is probably a well-defined coronoid process from 25 to 30 mm. behind the symphysis, measured around the curve of the jaw; such a structure would fit neatly into the subtemporal fossa. The inferior margin of the jaw curves upward from the articular region to the symphysis, paralleling the curve from cheek to premaxilla in the skull. A prominent retroarticular process is present. The dorsal margin of the prearticular bone shows a medial thickening, presumably for reinforcement of the articular element, which was probably present only as the proximal end of meckel's cartilage. Size of the adductor fossa is indeterminable from the material at hand.

Axial Skeleton
(text-fig. 3)

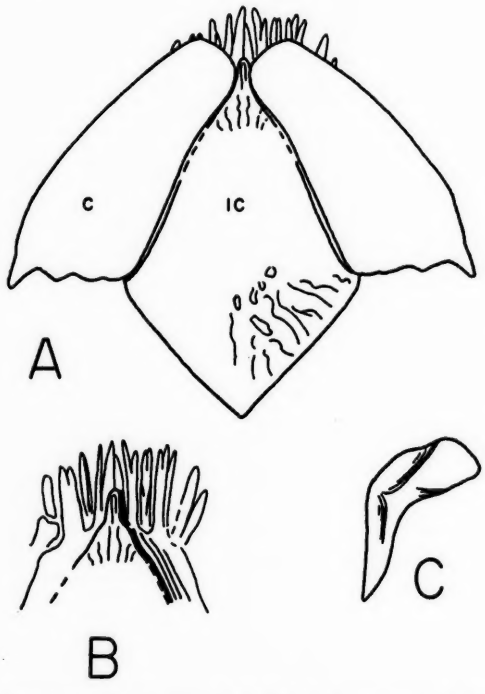
Each vertebral centrum is about 5 mm. in diameter and about 4 mm. long, and is somewhat more heavily ossified than in *Eobrachyops* or *Trimerorhachis*. The intercentrum



TEXT-FIG. 3—Vertebral segments of *A. vorax*, ×1.5. A and C, right lateral aspect, neural arches restored. B, ventral aspect, showing tips of pleurocentra. D, intercentrum, anterior aspect. Reference letters: I, intercentrum; NS, neural arch; PL, pleurocentrum.

forms a nearly complete ring, open at the top (text-fig. 3,D); it is wedge-shaped in lateral aspect. The paired pleurocentra consist of curved plates that fit the sides of the chordal region of the column, and are roughly fusiform in lateral aspect. An interesting feature is the great dorsoventral extent of both elements, giving the centrum a superficially embolomerous appearance. Indeed, the tips of the pleurocentra are visible on the ventral surface (text-fig. 3,B), but in spite of their close approach to each other they are never fused into a single element of embolomerous type, and the organization of the centrum is basically rhachitomous. The centrum of *Acroplous* is a good representative of Romer's protorhachitomous category (Romer, 1947). The neural arches are ill-characterized and poorly preserved; none are in proper relationship to their centra. The best examples show a fairly well-defined anterior zygapophysis, below which the pedicel descends to the chordal region as a thin lateral lamina, which is received in a V-shaped notch between intercentrum and pleurocentrum. Posterior zygapophysis is no more than a slight depression at the base of the low, blunt neural spine. Apparently no transverse processes are present, which suggests a highly flexible vertebral column.

Five ribs are preserved, each about 14 mm. long and slightly curved through most of its length. Two-thirds of the bone consists of shaft, which is elliptical in cross section and about 1.5 mm. in diameter. Its distal end is slightly expanded and blunt. Proximally the rib is flattened in a plane close to that of its curvature, and is about 3 mm. wide; tuberculum and head are fused.



TEXT-FIG. 4—Pectoral girdle of *A. vorax*, ×1.5. A, restoration of dermal pectoral girdle, B, detail of anterior end of interclavicle, showing elaborately pectinate ornamentation of anterior margin. C, cleithrum, (?)lateral aspect. Reference letters: C, clavicle; IC, interclavicle.

Pectoral Girdle

The dermal pectoral girdle is broad, flat, and sculptured ventrally, forming a large, subcutaneous, ventral thoracic shield (text-fig. 4,A). As restored it is approximately as wide as the skull. The interclavicle is shaped like a lozenge that has its anterior apex truncated. Its anterior margin is fantastically pectinate (text-fig. 4,B), bearing projections that are drawn out into spines of from 6 to 8 mm. in length (cf. total length of interclavicle of about 34 mm.). Some of the spines are co-ossified with the interclavicle and some are free, free spines generally alternating with fixed. The anterior margin of the interclavicle provides the origin of the longitudinal throat musculature, and in many labyrinthodonts is serrate or striated (Romer, 1947; personal communication); in few or none, however, is the ornament as well-developed as it is in *Acroplous*. The development of ornamentation of this nature may indicate development of stronger musculature for opening the mouth, in which case the condition of *Acroplous* represents a peculiarly powerful arrangement. But the ornamentation of *Acroplous* does not appear to lend itself to the flexibility that one might expect of jaw-opening musculature, and the necessity for such a powerful but relatively inflexible mechanism is obscure. It is possible that part of the movement in opening the mouth may have consisted of tilting the skull upward at a rather steep angle to the vertebral column (as suggested by the slope of the occiput and the well-developed occip-

ital crest). During this movement the jaw would be lowered and stabilized by the powerful throat musculature. As the jaws were brought together by the trigeminal musculature, the head would be brought down with a snap, which would also require stabilization of the lower jaw, especially if it were not resting on the substrate. The whole biting mechanism of the skull and jaws seems more nearly similar to that of predaceous fish than to that of frogs or even of alligators. Ventral to the pectinate anterior margin the sculptured surface of interclavicle is prolonged forward as a narrow medial tongue separating the clavicles anteriorly. The posterior portion of interclavicle projects behind the clavicles as a broad isosceles triangle. The antero-lateral margins of the two clavicles together form an anteriorly-convex half-circle, broken medially by intervention of interclavicle. The posterior margins of clavicles are coarsely and shallowly serrate and run transversely; the medial margins are almost straight, converging anteriorly. The postero-lateral margin and its posteriorly-produced angle turn upward and then medially to form the ascending process of the clavicle. The exact height of the ascending process is indeterminable due to the manner in which it is buried in matrix, but its base is strongly reinforced by a thickening at the margin of the clavicle, and by a ridge that runs upward on its medial side.

A bone tentatively identified as the cleithrum (text-fig. 4,C) is the only representative of the endochondral shoulder girdle. It is shaped like a hockey stick, and its short shaft, which forms the "handle," is grooved on its presumptive antero-lateral surface, for articulation with the ascending process of clavicle. The blade is rather heavy, with blunt distal end; its dorsal margin is rounded and flange-like.

Pelvic Girdle

A fragment of the pelvis shows part of ilium and ischium (text-fig 5,C). Both bones are thickest at their junction, but the acetabulum is not clearly defined. Ilium slants upward and slightly backward as a shaft of nearly circular cross-section about 2 mm. in diameter, and ischium tapers laterally and dorso-ventrally toward its broken posterior end. No trace remains of pubis, which probably was not ossified.

Limbs

Ossification in most of the disarticulated and scattered limb-bones is restricted to perichondral layers; the bones show few distinguishing characteristics. Many of the larger elements are partially crushed. Although identification of most individual bones is perforce tentative, their size indicates that *Acroplous* possessed extremities of moderate to large size. Restoration of the hind limb (text-fig. 5,B) is based on the assumption that the bones identified as ilium, femur, fibula, and metapodials 3 and 4, though not articulated, lie in proper proximo-distal relationship in the specimen at hand. The remainder of the limb is made up of scattered parts of appropriate size, as is the entire fore limb (text-fig. 5,A). Fragments of four digits, containing three and four articulated phalanges (a terminal phalanx in one), and ranging in total length from 10 to 12 mm., form the basis for restoration of foot and hand. Thus the general proportions of the extremities are probably depicted with fair accuracy, although no such claim is made for details like phalangeal formulae. The disparity in size between front and hind limb is rather "un-labyrinthodont," but nevertheless seems to be real. Of the two restorations, that of the hind limb is the more accurate; if either of them should be changed, the fore limb should be made larger.

The femur is about 16 mm. in length, with a minimum diameter of about 2 mm. in the middle of the shaft. The ends are flattened, and widen to a transverse dimension of about 6 mm. Bones identified as belonging to the leg are shorter and proportionately stouter than the femur, being 8 to 10 mm. long and about 2 mm. in smallest shaft diameter. They are not as flat and wide at their ends as is the femur. Some appear to bear a sharp edge along one side, which is interpreted as the attachment of an interosseous membrane. The presumed humerus is about 12 mm. in length and about 2 mm. in smallest shaft diameter. Elements of the forearm are about 7 mm. in length and 2 mm. in smallest diameter, and are otherwise similar to those assigned to the leg. The terminal

phalanges are cylindrical, sharp, and proportionately large for an amphibian, being rather lizard-like in appearance. No bones are safely ascribable to carpus and tarsus; presumably these regions were unossified in life.

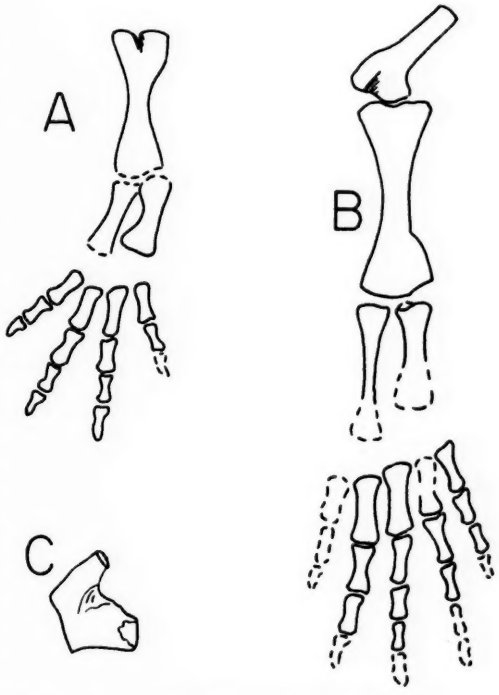
Scales

Three different types of integumental structures are associated in the specimen at hand, two of which appear to be osteoderms. One type of osteoderm consists of more or less regular polygons of very thin bone about 1 mm. in diameter, finely pitted on the superficial surface and smooth on the deep surface. This type occurs as a small patch of bones, each with its edges neatly fitted against the edges of its neighbors. Another type of osteoderm is in the shape of a broad isosceles triangle, the base of which is slightly convex; it measures about 3 mm. across the chord of the convexity. Its undersurface is smooth, and its superficial surface is marked either by prominent ridges that radiate from the apex of the triangle to the curved margin, or, in one specimen, by low but sharp spines. This type occurs as scattered individual bones. The third type of scale is paper-thin, with a sculpture that appears to consist of concentric ridges. These thin scales are very abundant, and occur as matted masses in a number of planes throughout the blocks containing the specimen. Their exact size and shape are undeterminable, but fragments measuring up to 3 mm. by 5 mm. have been noted.

RELATIONSHIPS

The skull of *Acroplous* is similar to that of *Eobrachyops* in short face, broad and deepened cheek region, posteriorly-projecting occiput, presence of an intertemporal bone, and restriction of lateral-line grooves to the orbital margin. Pterygoids bear a characteristic vertical flange in both skulls, and articulate with the basicranium by means of an internal process. The parasphenoids are generally similar in both forms, differing in details to be discussed below. Lower jaws are apparently similar in shape, and in development of retroarticular and coronoid processes.

Pelion Wyman (1867) and *Saurerpeton* Moodie (1909), two genera from the Linton, Ohio coal fauna, bear a close resemblance to each other and to *Acroplous* and *Eobrachyops*. Unfortunately, their taxonomic status is somewhat ambiguous. Nothing can be made of the type of *Pelion* except for the frog-like head shape and rather large limbs. The type of *Saurerpeton*, "*Sauropleura latithorax*" Cope (1897), indicates a skull of similar shape to that of *Pelion*, some features of the postorbital skull roof, a long tooth near the front of the lower jaw, and robust limbs of smaller proportions than those of *Pelion*. At least once (1874), Cope suggested it "possible but not probable" that *Pelion* and "*Sauropleura*" were congeneric.



TEXT-FIG. 5—Limbs of *A. vorax*, restored, ×1.5 A, left anterior limb. B, left posterior limb. C, fragment of ilium and ischium?

In reviewing the Linton fauna, Romer (1930) described as *Pelion* a form that resembles *Saurerpeton* in size and shape of skull, adding details of the dermal roof and palate, and showing anterior palatal vacuities for reception of symphyseal tusks. He also erected the genus *Branchiosauravus* for a smaller amphibian of shorter post-orbital length but similar dermal pattern. Steen

(1930) redescribed *Pelion* from a specimen in the British Museum that shows an excellent parasphenoid and pterygoid but no anterior palatine vacuities. She noted that her specimen differs from Romer's in configuration of the back of the parasphenoid. In 1947 Romer assigned both his and Steen's specimens of *Pelion* to *Saurerpeton* on the basis of anterior palatal vacuities (which he believed Steen had mistaken for internal nares), greater post-orbital length, and smaller limbs. At the same time he reduced *Brachiosauravus* to synonymy with *Pelion*. He described *Saurerpeton* as having a flattened skull, although in his 1930 paper he mentioned that the quadrate ramus of pterygoid, though short, is "moderately deep."

Watson (1956), with the aid of improved techniques of preparation, further restored Steen's specimen of *Pelion*. He agreed with her that palatal vacuities are lacking, and re-emphasized the difference in posterior palate between Steen's animal and Romer's *Saurerpeton*, concluding that it is congeneric with Romer's *Pelion* of 1947 ("*Branchiosauravus*" of 1930) rather than with *Saurerpeton*. Steen noted a deep lateral pterygoid flange in *Pelion* but believed the skull to be flat; Watson showed that the pterygoid flange indicates a skull deepened in the cheek region like that of *Eobrachyops* and *Acroplous*, and suggested also that the occiput slants back behind the skull table.

Saurerpeton is a genus similar in most respects to *Pelion*, distinguished with certainty only in greater length of skull table, presence of symphyseal tusks and palatal openings, somewhat larger size, and proportionately smaller limbs. The skull is possibly but not certainly flatter than that of *Pelion* and details of the occiput are not known.

Watson made a convincing case for placing *Pelion* close to the ancestry of *Eobrachyops*, based chiefly upon the presence in both forms of a flanged pterygoid with internal process, and projecting occiput. He showed that the basicranial articulation of the palate is similar in *Pelion* and *Eobrachyops*, taking place between the internal process and a facet on the anterior margin of the broad parasphenoid wing. The body of parasphenoid in *Pelion* is flat and shield-shaped; it remains almost as broad as the parasphenoid wings as it passes under the otic region, and only tapers to a rounded point in the occipital region. In *Eobrachyops*, on the other hand, the body of parasphenoid narrows abruptly behind the wings; posteriorly its lateral margins are turned up to enwrap the basioccipital and gain contact with the exoccipitals. *Pelion* has a well-developed otic notch, while *Eobrachyops* has none. In both the posterior part of parasphenoid and otic notch *Pelion* represents a more primitive than that seen in *Eobrachyops*.

In *Acroplous* the body of parasphenoid is narrowed immediately behind the wings, much as in *Eobrachyops* but not to the same extent; in breadth of the post-alar region of parasphenoid *Acroplous* appears to be intermediate between *Pelion* and *Eobrachyops*. In its small otic notch also the Kansas form occupies an intermediate position. The contour of the parasphenoid wing proper resembles more closely the condition in *Pelion*, being directed laterally instead of rostrally. The actual articular surface of parasphenoid is provided by a flange on its anterior margin in *Pelion* and *Eobrachyops*, but not in *Acroplous*, where most of the basicranial component of the joint probably consists of a cartilagenous basipterygoid process. In this respect *Acroplous* does not appear to be intermediate between the other two genera, but rather less specialized than either. In various details of the dermal pattern of skull roof and palate, *Acroplous* bears a closer resemblance to *Pelion* than to *Eobrachyops*, and generally provides an excellent morphological intermediate between the two. In the presence of symphyseal tusks and palatal vacuities for their accommodation, *Acroplous* resembles *Saurerpeton* more than *Pelion* and *Eobrachyops*. In Romer's restorations of *Saurerpeton* ("*Pelion*" of 1930; *Saurerpeton* of 1947) the articular region of the quadrate appears to lie well in front of the occipital condyle, while in those of *Pelion* the quadrate lies at the same level as the occipital condyle. Romer's restorations do not show a projecting occiput in either animal, but Watson restored *Pelion* with an occiput that projects beind the skull table as it does in *Acropolus* and *Eobrachyops*. The occiput of *Saurerpeton* is poorly known, but even if it does not project posteriorly, the relation between quadrate and occipital condyle ap-

pears to be similar to that of *Pelion*, and to foreshadow the condition of the Permian forms. These facts suggest strongly that *Saurerpeton* should be included with *Pelion* in the group of animals that were ancestral to *Acroplous* and *Eobrachyops*. The morphologically annectant position of *Acroplous* between *Pelion* and *Saurerpeton* on one hand and *Eobrachyops* on the other is supported by its stratigraphic position at the bottom of the lower Permian, approximately midway between the upper Pennsylvanian level of the Linton fauna, and the Arroyo, from which *Eobrachyops* is believed to have come.

Trimerorhachis, a short-faced, flattened labyrinthodont of the American lower Permian, resembles the genera discussed above in pterygoid articulation, and in having a deep basioccipital combined with flattened basisphenoid. Watson (1956), in discussing the relationship between *Trimerorhachis* and *Eobrachyops*, conceded that these features are unusual, and that they may well be evidence of common ancestry. He concluded, however, that differences between the two genera outweigh the similarities, which are due merely to "retention of primitive qualities and somewhat similar skull shape," and was unwilling to support a particularly close relationship between them. He listed a number of characters to illustrate these differences, in several of which *Acroplous* resembles *Trimerorhachis* more closely than it does *Eobrachyops*. Some of these characters, such as the presence of an otic notch, greater contribution of exoccipitals to the occipital condyle, and failure of clavicles to meet in front of the interclavicle, are primitive, and show merely that *Acroplous* is closer to the common stem from which *Eobrachyops* and *Trimerorhachis* sprang. Other characters in which *Acroplous* resembles *Trimerorhachis* and differs from *Eobrachyops*, such as reduced inter-orbital distance and narrow midline elements, relations of vomer, palatine, and maxilla to the choana, and presence of symphyseal tusks and anterior palatal openings, cannot be explained on the basis of primitiveness alone, but serve to emphasize the annectant nature of *Acroplous*, and to suggest that although *Trimerorhachis* represents a line collateral rather than ancestral to *Eobrachyops*, the relationship is closer than Watson implies.

Romer (1947) pointed out the similarity of *Trimerorhachis* to *Saurerpeton* in flattened habitus, relatively feeble limbs, elongate post-orbital region of the skull, and dentition and pterygoid articulation, and suggested that *Saurerpeton* may represent a Pennsylvanian ancestor of *Trimerorhachis*. From this line he tentatively derived *Dvinosaurus*, a short-faced, brachyopid-like amphibian from the upper Permian of Russia. He did not believe that *Dvinosaurus* is a true brachyopid, however. Since *Eobrachyops* was not available to him at the time, he derived the brachyopids from later neorhachitomes chiefly on the basis of similarities in the post-orbital region of the skull.

The name *Eobrachyops* indicates Watson's belief that that form is the earliest representative of the brachyopid line. His argument that it sprang from an animal much like *Pelion* is plausible, but his inclusion of *Dvinosaurus* in the line of brachyopid descent, coupled with exclusion of *Trimerorhachis* from it, becomes inconsistent in the light of evidence provided by *Acroplous*. *Acroplous* corroborates closely the relation Watson described between *Pelion* and *Eobrachyops*, but in addition tends to bring animals of the *Saurerpeton-Trimerorhachis* type of organization into closer relationship to them. In doing so it re-emphasizes the *Trimerorhachis*-like aspects of *Dvinosaurus*. The animals discussed above appear to form two lines of descent which must have begun to differentiate by upper Pennsylvanian times. One line is that of *Pelion-Eobrachyops* described by Watson, and the other that of *Saurerpeton-Trimerorhachis*, of Romer. *Acroplous* makes a good morphological intermediate between *Pelion* and *Eobrachyops* in most respects, but carries features reminiscent of the other line that indicate that the two were still relatively close in the lower Permian. The presence of symphyseal tusks may be a character which appears more or less at random within the two closely-related lines. On the other hand, it may be an indicator of true phyletic relationship, relatively little affected by immediate pressures of selection. If this second interpretation is correct, *Acroplous* makes a better ancestor for *Dvinosaurus* than does *Eobrachyops*. *Acroplous* itself is perhaps a derivative of *Saurerpeton* which has become adapted to an

ecological niche similar to that of *Eobrachyops* and shows strong morphological parallelism to the latter. *Dvinosaurus* then is a terminal representative of this type of organization in the line stemming from *Saurerpeton*, and *Trimerorhachis* shows a more conservative modification of the same stock. The brachyopids, derived from *Eobrachyops* as Watson suggests, arrived somewhat later at the type of organization represented by *Dvinosaurus* in late Permian times, but do not include *Dvinosaurus* in direct line from *Eobrachyops*. Some support is given this notion by Romer's statement (1947, p. 57) that symphyseal tusks are unknown in brachyopids.

Postcranial material is not particularly definitive, but tends in general to support the above arrangement. The central vertebral elements are strongly reminiscent of *Trimerorhachis* in shape and relationship, differing chiefly in the greater depth of the pleurocentra. Depth of the pleurocentra is the only respect in which the vertebra resemble those of *Eobrachyops* more closely than those of *Trimerorhachis*. The central elements appear to be somewhat more heavily ossified in *Acroplous* than in either *Eobrachyops* or *Trimerorhachis*. Neural arches are not well enough preserved to permit relating them to either genus; they appear to consist of separate lateral ossifications in all three genera. The dermal pectoral girdle of *Acroplous* is very similar to that of *Trimerorhachis*. The limbs of *Eobrachyops* are not known. Those of *Acroplous* are similar to *Trimerorhachis* except for greater proportionate size and larger, reptile-like terminal phalanges.

A formal taxonomic placement of *Acroplous* is difficult because of the annectant nature of the beast. Watson treats *Eobrachyops* as an early member of the "brachyopid line," without formally placing it in the family Brachyopidae or any other family, and deals with *Pelion* in similar fashion. His procedure implies that the family Brachyopidae is a tremendously long vertical structure that includes both the most primitive members and the terminal memvers of the line; such an arrangement adheres closely to a possible phylogeny, which is one of the things a good classification is supposed to do. Yet between *Pelion*, in the upper Pennsylvanian, and the lower Triassic brachyopids there is a tremendous temporal gap and also a rather respectable morphological gap. The morphological resemblances between *Pelion* and its contemporary *Saurerpeton*, and between *Eobrachyops* and *Acroplous*, are close enough that one is forced back upon Romer's more horizontal classification, which groups the families Peliontidae, Trimerorhachidae, and Dvinosauridae together as the superfamily Trimerorhachoidea. Both *Eobrachyops* and *Acroplous* can be included in the superfamily with but slight modification of Romer's definitions (1947, p. 312). A phrase such as "otic notch often poorly-developed or lacking" should be included in describing the entire superfamily, rather than "otic notch not prominent" being applied to the Trimerorhachidae alone; this permits placing *Eobrachyops* in the family Peliontidae where all other features indicate it belongs. The phrase "skull much flattened" should be modified to "strong tendency toward flattening of skull" in the description of the Trimerorhachidae, so that *Acroplous* may be admitted to the family. Since *Saurerpeton*, *Acroplous*, and *Trimerorhachis* all have well-developed symphyseal tusks and anterior palatine openings, perhaps this feature should be indicated in diagnosing the Trimerorhachidae, at least to contrast them with the Peliontidae. This arrangement fits the phylogenetic conclusions reached in the preceding paragraphs; *Pelion* and *Eobrachyops*, perhaps most closely related to ancestors of the brachyopids, are thus brigaded with *Saurerpeton* and *Trimerorhachis*, the annectant *Acroplous* forming the link between the two groups. The brachyopids, although they may be descended from a form near *Eobrachyops* as Watson suggests, must be placed in a separate superfamily because of their morphological difference, which is emphasized by the temporal gap between the archaic Permo-Carboniferous trimerorhachoids and the definitive Triassic brachyopids.

ADAPTIVE SIGNIFICANCE OF HABITUS OF *ACROPLOUS*

Consideration of the snout, jaw structure, and dentition of *Acroplous* invites conjecture about the habits of the animal. The extreme dorsal position of the nares, and their proximity to the orbits is unusual among labyrin-

thodonts, and is encountered for the most part in extremely short-faced, flattened forms like the brachyopids and metoposaurs. In these animals it appears that the nares have been forced dorsally and close to the orbit chiefly because of restriction of space in the snout region. In *Acroplous*, on the other hand, although the face is short the snout remains deep; the nares appear to have migrated up in front of the eyes in response to selective forces other than restriction of space on the snout. As suggested above (ms. p. 13), the relation of nares and orbits is rather frog-like, indicating that *Acroplous* may have spent a good part of its time at the surface of the water, using its nostrils as snorkels and its eyes as periscopes.

The deep, anteriorly-placed quadrate and curved lower margin of the skull allows tremendous gape of the mouth, and together with the impressive dental armament suggests a highly predaceous habit. In gape and dentition *Acroplous* is similar to many other labyrinthodonts, including flattened forms whose habitus fitted them best for lying in wait on the bottom of the Permian ponds. However, *Acroplous* does not show the flattening of these forms, and its proposed habit of basking at the surface suggests that it was a much more active swimmer than its flatter contemporaries. The general impression that one receives from skull and jaws in lateral aspect is that of a pike-like characin fish such as *Sarchodaces* (Gregory, 1951, fig. 9.52A). The body may have been fusiform with somewhat flattened head, perhaps on the general pattern of *Amia calva*. This is not to say that *Acroplous* was actually pike-like, or even *Amia*-like in habit, but merely to suggest that it was more of a limnetic than a pedonic form. Instead of lying on the bottom to await its prey, *Acroplous* may have spent part of its time drifting close to the surface or among weeds, and snapping at choice victims or capturing them after a short charge from this position. The well-developed dermal pectoral girdle shows that the animal also spent considerable time on the substrate. The limbs were undoubtedly very effective in walking on the bottom of the pond, and are probably large enough to have served in good stead out of water as well as in it. The stout ungual phalanges resemble more nearly those of a terrestrial form than a persistent water dweller such as *Trimerorhachis*.

Acroplous was probably a fairly active animal, freer of the water than *Trimerorhachis*, but still dependent upon it not only for protection, but also for most if not all of its prey. Its ecological position in the pond fauna was rather unusual for an amphibian of Permian times, since it tended to utilize higher strata of water than most of its known contemporaries. *Eobrachyops* may have been of somewhat similar habit, although it does not show the specialization of the nares seen in *Acroplous*. Indeed, the peculiarly deep cheek region and inverted-U-shaped palate of the brachyopids may have orginated as early members of the line came to utilize a limnetic or semi-limnetic ecological niche. In general, however, the limnetic habit was not maintained; advanced brachyopids and *Dvinosaurus* show a reduction in depth of the cheek region, indicating an increasing tendency to utilize the pond floor as do most late members of other labyrinthodont lines. *Batrachosuchus*, a brachyopid from the lower Triassic of Africa, may demonstrate an exception to this tendency. In restorations published by Watson (1956), this form appears to have the nares placed dorsally and close to the orbits, a deeper cheek region than most of its contemporaries, and the quadrate lying well in front of the occiput. It appears also to have more enlarged tusks in its dentition than do its contemporary relatives, although like them it has no symphyseal tusks. In the features in which it differs from its contemporaries, *Batrachosuchus* is reminiscent of *Acroplous;* thus it may be a late representative among the brachyopids of a similar adaptive type.

OTHER OCCURRENCES OF *ACROPLOUS*

Romer (1952) describes a parasphenoid, humerus, and lower jaw fragment from the "Pittsburg limestone" (Moran, 1952) of the Conemaugh group, which he refers tentatively to *Saurerpeton obtusum*. The parasphenoid is exposed in ventral aspect, and shows a fine ventral keel. No carotid foramina are visible. However, in general shape, size, and nature of the pterygoid articulation, this bone appears to be indistinguishable from the parasphenoid of *Acroplous*, to

which it should probably be referred. The Pittsburg humerus is also similar to that of *Acroplous* with respect to both size and shape, but resembles equally the humerus of other small rhachitomes that were present in the same environment. The jaw may also belong to *Acroplous*, although like the humerus it is not distinctive enough to warrant referring it to that genus unconditionally.

From a number of localities in the Dunkard series Romer describes a series of vertebral elements that are similar to those of *Trimerorhachis* but not directly referable to it. In the pointed appearance of the dorsal ends of the intercentra and in the size of the pleurocentra these vertebrae bear a strong resemblance to those of *Acroplous*. Limb elements from the Dunkard are of appropriate size to be referred to *Acroplous*, but like those from lower levels they lack distinctive characters and may belong to other small rhachitomes.

On the basis of parasphenoid and veretebral elements, it seems fairly certain that the geographic range of *Acroplous* extended into the Appalachian region during Permo-Carboniferous time.

REFERENCES

ADAMS, J. E., et al., 1939, Standard Permian section of North America: Am. Assoc. Petroleum Geologists Bull., v. 23, p. 1673–1681.

BROILI, F., 1913, Ueber zwei Stegocephalenreste aus dem Texanischen Perm: Neues Jahrb. f. Min. Geol. u. Paleontol., v. 1913, p. 96–100.

COPE, E. D., 1874, Supplement to the extinct Batrachia, Reptilia, and Aves of North America. I. Catalogue of the air-breathing Vertebrata from the Coal Measures of Linton, Ohio: Am. Philos. Soc. Trans., v. 15, p. 261–278.

——, 1897, On new Paleozoic Vertebrata from Illinois, Ohio, and Pennsylvania: Am. Philos. Soc. Proc., v. 36, p. 71–90.

DOTT, R. H., 1941, Regional stratigraphy of Mid-Continent: Am. Assoc. Petroleum Geologists Bull., v. 25, p. 1619–1705.

GREGORY, W. K., 1951, Evolution emerging: The Macmillan Company, New York.

HATTIN, D. E., 1957, Depositional environment of the Wreford megacyclothem (lower Permian) of Kansas: Kansas Geol. Survey, Bull. 124, p. 1–150.

JEWETT, J. M., 1933, Evidence of cyclic sedimentation in Kansas during the Permian period: Kansas Acad. Sci. Trans., v. 36, p. 137–140.

——, 1941, The geology of Riley and Geary Counties, Kansas: Kansas Geol. Survey, Bull. 39, p. 1–164.

KING, P. B., 1942, Permian of West Texas and southeastern New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 26, p. 535–763.

MOODIE, R. L., 1909, New forms (extinct Amphibia) from the Carboniferous: Jour. Geology, v. 12, p. 38–82.

MOORE, R. C., 1935, Late Paleozoic crustal movements of Europe and North America: Am. Assoc. Petroleum Geologists Bull., v. 19, p. 1253–1307.

——, et al., 1951, The Kansas rock column: Kansas Geol. Survey, Bull. 89, p. 1–132.

MORAN, W. E., 1952, Fossil vertebrates of the tri-state area. Art. 1. Location and stratigraphy of known occurrences of fossil tetrapods in the upper Pennsylvanian and Permian of Pennsylvania, West Virginia, and Ohio: Carnegie Mus. Ann., v. 33, p. 1–44.

ROMER, A. S., 1930, The Pennsylvanian tetrapods of Linton, Ohio: Am. Mus. Nat. History Bull., v. 59, p. 77–147.

ROMER, A. S., 1935, Early history of the Texas redbeds vertebrates: Geol. Soc. America Bull., v. 46, p. 1597–1658.

——, 1947, Review of the Labyrinthodontia: Mus. Comp. Zoology (Harvard) Bull., v. 99, p. 1–368.

——, 1952, Fossil vertebrates of the tri-state area. Art. 2. Late Pennsylvanian and early Permian vertebrates of the Pittsburgh-West Virginia region: Carnegie Mus. Ann., v. 33, p. 47–110.

SCHUCHERT, C., 1935, Correlations of the more important marine Permian sequences: Geol. Soc. America Bull., v. 46, p. 1–45.

STEEN, M. C., 1930, The British Museum collection of Amphibia from the Middle Coal Measures of Linton, Ohio: Zool. Soc. London Proc., v., 1930, p. 849–891.

THOMPSON, M. L., 1954, American Wolfcamp fusulinids: Univ. of Kansas, Paleont. Contr., Protozoa, Art. 5, p. 1–226.

WATSON, D. M. S., 1956, The brachyopid labyrinthodonts: British Museum (Nat. History), Geology Bull., v. 2, p. 318–391.

WYMAN, J., 1858, On some remains of batrachian reptiles discovered in the coal formation of Ohio; Am. Jour. Sci., ser. 2, v. 25, p. 158–164.

MANUSCRIPT RECEIVED JUNE 20, 1958

JOURNAL OF PALEONTOLOGY V. 33, NO. 1, P. 179–185, PLS. 29, 30, JANUARY 1959

NEW GENERA OF EARLY CRETACEOUS (ALBIAN) AMMONITES FROM ALASKA[1]

RALPH W. IMLAY
U. S. Geological Survey, Washington, D. C.

ABSTRACT.—New genera and species of Albian ammonites from Alaska include *Moffites robustus* Imlay, *Freboldiceras singulare* Imlay, *Kennicottia bifurcata* Imlay, and *Parasilesites bullatus* Imlay. The new species of *Moffites* and *Kennicottia* are associated with *Leconteites deansii* (Whiteaves) and are of early Albian age. The new species of *Freboldiceras* is associated with *Beudanticeras glabrum* (Whiteaves) and *Lemuroceras* sp. aff. *L. indicum* (Spath) and is probably of early Albian age. The new species of *Parasilesites* is associated with *Brewericeras breweri* (Gabb), *Cleoniceras* sp., *Valdedorsella* sp., *Hulenites* sp., and *Lemuroceras* (*Subarcthoplites*) sp. aff. *L. belli* McLearn. This faunule is either early Albian or early middle Albian in age.

INTRODUCTION

STUDIES of Early Cretaceous (Albian) ammonites from Alaska have demonstrated that some of the ammonites belong to new genera. These are validated herein in order that the names may be used in the near future in stratigraphic papers and in making fossil identifications for field parties. The type specimens are deposited in the collections of the U. S. National Museum. Descriptions of the fossil localities listed in the text under the new genera *Moffites*, *Kennicottia*, and *Parasilesites* have been published by Moffit (1938, p. 81–86). U.S.G.S. Mesozoic locality 24877 listed under the new genus *Freboldiceras* is at the head at Billy Creek in the eastern part of the Talkeetna Mountains at Lat. 62°01′40½″N., Long. 147°39′18″W.

Fossil and Correlation

Moffites robustus Imlay, n. sp., and *Kennicottia bifurcata* Imlay, n. sp., are associated with the ammonites *Leconteites deansii* (Whiteaves), *Ptychoceras* sp. cf. *P. laeve* (Gabb), *Anagaudryceras aurarium* (Anderson), *Callizoniceras*, and the pelecypod *Aucellina* within 200 to 300 feet of gray shale and brown sandstone at the base of the Kennicott formation (Moffit, 1938, p. 71). A little lower in the same 200 to 300 feet of beds have been obtained *Leconteites modestus* (Anderson), *Puzosigella* spp., and *Anagaudryceras aurarium* (Anderson). These ammonites furnish a correlation with the *Leconteites lecontei* zone in California (Murphy, 1956, p. 2118), which is correlated with the early Albian of Europe because of the presence of the ammonite *Douvilleiceras* and because it underlies other beds containing ammonites of early to middle Albian age. It appears, therefore, that the beds characterized by *Moffites*, *Kennicottia*, and *Leconteites deansii* (Whiteaves) are only slightly younger than the zone of *Leconteites lecontei*. The presence of *Callizoniceras* is fairly good evidence of an age not younger than early Albian.

Parasilesites bullatus Imlay, n. sp., has been found only at one locality (Mes. loc. 9492), where it is associated with many other ammonites and with small specimens of *Inoceramus* that resemble immature forms of *I. comancheanus* Cragin (equals *I. anglicus* Woods). Some of the associated ammonites include *Tetragonites* sp. aff. *T. timotheanus* (Pictet), *Valdedorsella* sp., *Brewericeras breweri* (Gabb), *B.* sp. cf. *B. hulense* (Anderson), *Hulenites* sp. cf. *H. reesidei* (Anderson), *Cleoniceras* sp., *Puzosia* sp., *Desmoceras* sp., and *Lemuroceras* (*Subarcthoplites*) sp. aff. *L. belli* McLearn.

The stratigraphic position of this assemblage relative to that containing the new genera *Moffitites* and *Kennicottia* has not been determined in the field, but the presence of *Brewericeras breweri* (Gabb) indicates that it is higher and should be about

[1] Publication authorized by the Director, U. S. Geological Survey.

the same age as the *B. hulense* zone in California (Murphy, 1956, p. 2118). The presence of such genera as *Valdedorsella* and *Hulenites* suggests that its age is not younger than early Albian. The presence of *Cleoniceras* indicates a late early Albian to middle Albian age.

The association of *Lemuroceras* (*Subarcthoplites*) sp. aff. *L. belli* McLearn with *Brewericeras breweri* (Gabb) at Mesozoic locality 9492 is interesting as it provides a correlation with the *Lemuroceras belli* zone of northern Alaska and the western interior of Canada and with the *Brewericreas hulense* zone of the Pacific coast. In the western interior of Canada the zone of *Lemuroceras belli* occurs a little below the beds characterized by *Gastroplites kingi* in the upper part of the Loon River formation, the lower part of the Buckinghorse formation, and in the Clearwater formation (McLearn, 1945, pl. 3, figs. 17,18; McLearn & Kindle, 1950, p. 86, 93) and has been correlated with the early middle Albian (Mellon & Wall, 1956, p. 11; Stelck, Wall, Bahan, & Martin, 1956, p. 9; Stelck, 1958, p. 4). In northern Alaska the zone of *Lemuroceras belli* underlies the zone of *Gastroplites kingi* by at least 600 feet of beds that contain *Cleoniceras*. That genus ranges upward another 2000 feet or more through the lower part of the range of *Gastroplites kingi*. This extended range of *Cleoniceras* seems sufficient to account for its total range in Europe and suggests, therefore, that the underlying *Lemuroceras belli* zone is of early Albian age.

Dating the *Lemuroceras belli* zone by Canadian paleontologists as early middle Albian is based on the position of *Lemuroceras* above beds containing *Cleoniceras* and *Sonneratia* (Stelck, Wall, Bahan & Martin, 1956, p. 9) and on the occurrence of *Lemuroceras* in Madagascar in the *Douvilleiceras mammillatum* zone (Collignon, 1949, p. 109, 114–117). Likewise the *Brewericeras hulense* zone of the Pacific Coast may be correlated with the *Douvillericeras mammillatum* zone because of the presence of certain species of *Douvilleiceras* (Anderson, 1938, p. 174–176; Murphy, 1956, p. 2114). Both correlations need more substantiation, however. In particular the evidence cited for the Canadian fossils has not been adequately documented, the total range of *Lemuroceras* has not been demonstrated, and even the presence of *Lemuroceras* in Canada has been questioned (Casey, 1954, p. 111). Also dating these North American zones in question as definitely early Albian or middle Albian is academic at present considering that some European authorities assign the *Douvilleiceras mammillatum* zone to the early middle Albian (Spath, 1941, p. 668) and others assign it to the late early Albian (Breistroffer, 1947, p. 24,51,53; Wright, 1957, p. L128).

Freboldiceras singulare Imlay, n. sp., from the Talkeetna Mountains is associated with *Beudanticeras glabrum* (Whiteaves) (1889, p. 172, pl. 24, figs. 1a,b), a new species of *Beudanticeras* similar to a specimen figured by McLearn (1945, pl. 5, fig. 6) from Canada, a new species of *Lemuroceras* similar to *L. indicum* (Spath) (1933, p. 801, pl. 28, figs. 4a,b,5a,b) from India, and to *L.* sp cf. *L. indicum* (Spath) from Canada (McLearn, 1945, pl. 5, fig. 4). These ammonites are closely similar to, and in part identical with certain ammonites from the Clearwater, Gates, Moosebar, and Buckinghorse formations in the western interior of Canada (McLearn, 1945, pl. 4, pl. 5, figs. 4–6). In contrast they have almost nothing in common with the ammonite faunules of the Chitina Valley, Alaska. The presence of *Lemuroceras* suggests an age not greatly different from

---

EXPLANATION OF PLATE 29

All figures natural size unless otherwise indicated

FIGS. *1–8*—*Parasilesites bullatus* Imlay, n. sp. *1, 2, 6–8*, holotype USNM 129872 from USGS Mes. loc. 9492. Suture-line (×3) drawn at whorl height of 7 mm. *3–5*, paratype USNM 129873 from USGS Mes. loc. 9492 showing sculpture of immature specimens.

9–14—*Moffitites robustus* Imlay, n. sp. *9*, suture (×2) drawn at whorl height of 19 mm. from paratype USNM 129875a from USGS Mes. loc. 9972. *10–12*, paratype USNM 129875b. *13,14*, holotype USNM 129874 from USGS Mes. loc. 2191.

1

2

3

4

5

6

7

X3

8

X2

9

10

11

12

13

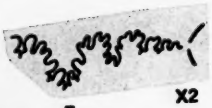
14

1

2

3

4

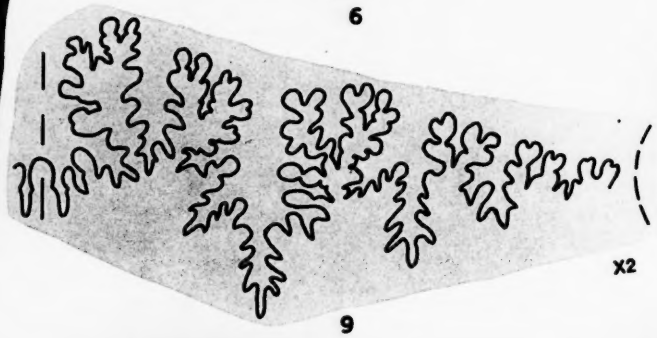


5 X2

6

7 X2

8



9 X2

10

11

12

13

the faunule characterized by *Brewericeras breweri* (Gabb) at Mesozoic locality 9492, but the species of *Lemuroceras* in the two faunules are distinct and the composition of the faunules affords no evidence as to which is the younger. The only clue as to relative stratigraphic position is a statement by Canadian paleontologists that *Lemuroceras* sp. cf. *L. indicum* (Spath) occurs in the lower part of the Loon River shale (Stelck, Wall, Bahan and Martin, 1956, p. 6,10). If so, it occurs lower stratigraphically than *Lemuroceras belli* McLearn from the upper part of the Loon River shale.

SYSTEMATIC DESCRIPTIONS

Family DESMOCERATIDAE Zittel, 1895

Subfamily PUZOSIINAE Spath, 1922

Genus MOFFITITES, n. gen.

This genus is characterized by an inflated shell, moderate involution, a whorl section that changes from ovate to convate during growth, by flexuous ribs and constrictions that arch forward strongly on the venter, by frequent bifurcation of the primary ribs into somewhat weaker secondary ribs near the middle of the flanks, by a tendency of the secondary ribs to weaken and become striate as they near the middle of the venter, by the occurrence of flared ribs adjacent to the constrictions, and by having a desmoceratid suture line whose auxiliaries descend gradually toward the umbilical seam.

It differs from the new genus *Kennicottia*, with which it is associated, by being much more inflated, by having much stronger primary ribs, and by a tendency of its secondary ribs to become striate on the venter. Its ornamentation bears some resemblance to that of *Pseudohaploceras* Hyatt (1900, p. 500), but it is easily distinguished by having regularly furcating ribs and a coronate whorl section. It resembles *Valdedorsella* Breistroffer (1947, p. 60) in shape and involution, but the differentiation of its ribs into primaries and secondaries and the considerable strength of its primary ribs permit easy separation of the genera. The same features distinguish it readily from genera within the Holcodiscidae, such as *Astieridiscus* Kilian (1910, p. 265).

The type species of *Moffites* is *M. robustus* Imlay, n. sp.

This genus is named for Fred H. Moffit in recogniton of his many important contributions to Alaskan geology as a member of the U. S. Geological Survey.

MOFFITITES ROBUSTUS Imlay, n. sp.

Pl. 29, figs. 9–14

The species is represented by 30 specimens. Shell stout, moderate in size. Whorls ovate depressed, becoming stouter during growth, embracing about three-fifths. Flanks gently convex on immature specimens, becoming highly convex on adults. Venter highly arched in immature specimens, becoming broadly rounded on adults. Umbilicus moderate in width; wall inclined steeply, fairly high, rounding evenly into flanks. Body chamber incomplete, but represented by at least half a whorl.

The ribbing is gently flexuous on the flanks, is arched forward on the venter, and is variable in density. The primary ribs are moderate in strength, are triangular in section, become stronger ventrally, and are generally narrower than the interspaces. They begin low on the umbilical wall, incline forward slightly on the wall and on the lower third of the flanks, and then recurve gently near the middle of the flanks where they pass into, or are replaced by much weaker secondary ribs.

On immature specimens some of the primary ribs bifurcate near the middle of the

---

EXPLANATION OF PLATE 30

All figures natural size unless otherwise indicated

FIGS. *1–7*—*Freboldiceras singulare* Imlay, n. sp. *1–4,7*, holotype USNM 129868 from USGS Mes. loc. 24877. Suture-line (×2) drawn at whorl height of 15 mm. *5,6*, paratype USNM 129869a from USGS Mes. loc. 24877. Suture-line (×2) drawn at whorl height of 11 mm.

8–13—*Kennicottia bifurcata* Imlay, n. sp. *8,9,11–13*, holotype USNM 129870 from USGS Mes. loc. 9972. Suture-line drawn at whorl height of 29 mm. *10*, paratype USNM 129871 from USGS Mes. loc. 8873 showing distinct bifurcating ribs.

flanks. Others remain single on the flanks, but may be separated from each other, or from forked ribs by one or two secondary ribs that arise freely on the upper parts of the flanks. On the penultimate and body whorls most of the primary ribs bifurcate near the middle of the flanks and many of the pairs of secondary ribs are separated on the venter by one or two intercalated ribs. In many specimens the secondary ribs tend to weaken and become striate along the midventral area, but this tendency varies considerably from one specimen to another and from whorl to whorl. Tubercles are not present at any growth stage.

All whorls are marked by 6 to 8 constrictions that are flexuous on the flanks and arch forward on the venters. The constrictions are inconspicuous on the immature whorls, but become more pronounced adorally. On the outer whorls the constrictions are generally bounded by 1 or 2 swollen primary ribs on the flanks and by a forwardly projected swelling on the venter.

The suture line is desmoceratid in plan. Its auxiliaries descend gradually toward the umbilical seam, as in *Desmoceras*, *Pseudohaploceras*, or *Valdedorsella*.

The holotype at a diameter of 97 mm. has a whorl height of 43 mm., a whorl thickness of 52 mm., and an umbilical width of 31 mm. At a diameter of 66 mm. the other dimensions are 30, 40 and 20 mm. respectively. On paratype U.S.N.M. 129875b at a diameter of 56 mm. the other dimensions are 24, 37, and 18 mm. respectively.

Types.—Holotype, USNM: 129874; paratypes, USNM: 129875a,b, 129876a,b.

Occurrence.—USGS Mes. locs. 2147, 2191, 8873, 8875, 8876, 8878, 9489, 9967a, 9978, 14471, 14484, 14485. Fragments that possibly belong to this species occur at Mes. locs. 2173, 9971 and 14467.

Genus FREBOLDICERAS Imlay, n. gen.

This genus resembles *Callizoniceras* Spath (1923, p. 35) from the upper Barremian to lower Albian of Europe (V. Koenen, 1902, p. 58, pl. 9, figs. 5a–c, p. 60, pl. 28. figs. 5a,b, 6a–c,7; Wollemann, 1907, p. 36, pl. 5, figs. 4,4a,5,5a; Brinkmann, 1937, p. 8–10, figs. 4,5). It differs by being more involute; by its whorl section being higher and more narrowly rounded; by its primary ribs being more regularly-spaced, more swollen, and confined generally to the lower part of the flanks; by its constrictions being less regularly-spaced; and by having fewer secondary ribs. Its smooth body chamber and large size may be other distinctions. Its suture is very simple and closely resembles that of *Callizoniceras*. The type species of *Freboldiceras* is *F. singulare* Imlay, n. sp.

The genus is named in honor of Hans Frebold of the Canadian Geological Survey.

FREBOLDICERAS SINGULARE Imlay, n. sp.
Pl. 30, figs. 1–7

Four specimens of this species have been found in the Talkeetna Mountains at one locality. Shell compressed, discoidal. Whorls subovate in section, considerably higher than wide, thickest near umbilicus, embracing about two-thirds. Flanks gently convex in their lower parts, but tapering above to a narrowly rounded venter. Umbilicus fairly narrow, wall steeply inclined, rounding evenly into flanks. Body chamber represented by at least three-fifths of a whorl.

The ornamentation of the septate parts of the shell consists mostly of prominent, flexuous, regularly-spaced primary ribs, of deep, irregularly-spaced constrictions, and of flexuous striae. The primary ribs begin high on the umbilical wall, incline forward and become swollen near the umbilical edge, and then curve forward near the middle of the flanks where most of them pass into bundles of striae that arch forward gently on the flanks and venter. The primary ribs that adjoin constrictions continue across the flanks and venter, but are more prominent on the internal mold than on the shell. Some specimens at a few places have single, short secondary ribs that are intercalated between the primary ribs and continue across the venter. Where shelly material is preserved its surface is covered with fine, flexuous striae that is coarser on the primary ribs than on the interspaces. The periphery of the internal mold is strongly undulating. Wherever the shell is preserved the periphery is nearly smooth.

The adult body chamber is nearly smooth. Faint flexuous striae are present in a few places where shell layers are present. On the penultimate whorl the primary ribs become

much weaker adorally and are barely visible near the last-formed septa.

The suture-line is very simple. It greatly resembles that of the genus *Callizoniceras* (Wollemann, 1907, pl. 5, fig. 5a; V. Koenen, 1902, pl. 9, fig. 5c, pl. 38, figs. 6,7; Chaput, 1920, pl. 1, figs. 4a,b) in its broad first lateral saddle, in its first lateral lobe being slightly deeper than the ventral lobe, and in its auxiliary saddles not being retracted adapically near the umbilicus. In fact the auxiliaries ascend slightly as they approach the umbilical seam.

The holotype at a diameter of 55 mm., has a whorl height of 24 mm., a whorl thickness of 19 mm. and an umbilical width of 14 mm.

This species resembles "*Lemuroceras*" *irense* McLearn (1945, pl. 5, fig. 5, 1948, p. 2) from the Moosebar formation of British Columbia and probably belongs in the same genus. The preservation of the holotype of "*L.*"*irense* is not sufficient, however, to proove whether the resemblances are accidental or reflect generic relationships.

Types.—Holotype, USNM: 129868; paratypes, USNM: 129869a–c.

Occurrence.—USGS Mes. loc. 24877.

Genus KENNICOTTIA, n. gen.

This genus is characterized by being fairly involute, by the presence of persistent primary ribs that bifurcate fairly regularly near the middle of the flanks, by having flexuous ribs and constrictions that arch forward strongly on the venter, by the presence of some flared ribs adjoining the constrictions, by reduction of the secondary ribs along the midline of the venter, and by its suture line having regularly descending auxiliary lobes. It shows resemblances to *Pseudohaploceras* Hyatt (1900, p. 570) in amount if involution, whorl shape, suture-line, presence of flexuous constrictions and ribs, and presence of bifurcating ribs. It differs, however, by having a more subquadrate whorl section, a vertical umbilical wall, flatter flanks, weaker constrictions and flared ribs, and stronger, more regularly bifurcating primary ribs. It differs from *Valdedorsella* (Breistroffer, 1947, p. 60) in its whorl section being subquadrate instead of round and by the presence of bifurcating ribs. It differs from *Puzosia* by being considerably more involute, by the presence of bifurcating primary ribs, and by the auxiliary lobes of its suture line descending regularly instead of abruptly. The type species of *Kennicottia* is *K. bifurcata* Imlay, n. sp.

KENNICOTTIA BIFURCATA Imlay, n. sp.
Pl. 30, figs. 8–13

This species is represented by 13 specimens. Whorls subovate in immature specimens, becoming subquadrate in adult, embracing about three-fifths. Flanks gently convex, becoming less so during growth, rounding into highly arched venter. Umbilicus fairly narrow; wall low, vertical at base, rounding evenly into flanks. Body chamber unknown.

The ribbing is gently flexuous on the flanks and arched forward strongly on the venter. The primary ribs are somewhat stronger than the secondary ribs. They begin low on the umbilical wall, are highest on the edge of the wall and become rather broad ventrally. Most primary ribs bifurcate near the middle of the flanks, but some remain single, and some are indistinctly connected with secondary ribs. The secondary ribs are reduced in strength along the midline of the venter.

From 6 to 7 weak flexuous constrictions occur per whorl. They become more conspicuous adorally and are most conspicuous on the venter. On the adoral part of the holotype, they are bounded by swollen ribs.

The suture line is desmoceratid in type. Its regularly descending auxiliary lobes contrast with the retracted auxiliaries in *Puzosia*, but are comparable with those in *Pseudohaploceras*.

The holotype at a diameter of 63 mm. has a whorl height of 29 mm., a whorl thickness of 25 mm., and an umbilical width of 15 mm.

This species has a general resemblance to *Puzosia subquadrata* Anderson (1938, p. 186, pl. 45, figs. 3–5) from California, but differs by having much stronger primary ribs that bifurcate fairly regularly, by its ribbing being less flexuous, by its umbilical wall rounding more evenly into the flanks, and by its auxiliary lobes descending much more gradually toward the umbilical seam (compare Anderson, 1938, p. 183, text-fig. 3, no. 6).

Types.—Holotype, USNM: 129870; paratype, USNM: 129871.

Occurrence.—USGS Mes. locs. 8873, 9972, 14471, 14484.

Family SILESITIDAE Hyatt, 1900
Genus PARASILESITES Imlay, n. gen.

This genus is characterized by its fairly evolute shell, wide, shallow umbilicus, strongly flexuous ribs and constrictions, presence of umbilical bullae, occasional rib furcation on the flanks, and by the auxiliaries of its suture line descending only slightly. It differs from the Barremian genus *Silesites* by the presence of umbilical bullae, by the furcation of some ribs low on the flanks, by the ribs being inclined forward strongly at the edge of the umbilicus, and perhaps by its auxiliaries not curving adorally. It differs from the upper Aptian-lower Albian genus *Neosilesites* by the presence of umbilical bullae, by its ornamentation being much more sigmoidal, by its ribs branching much lower on the flanks, and by its primary ribs not splitting into many fine secondary ribs on the upper parts of the flanks. The suture line of *Parasilesites* is similar to that on small specimens of *Silesites* and *Neosilesites* (Fallot 1920*a*, p. 54,55; 1920*b*, p. 209–213). The tendency in the Silesitidae (Wright, 1957, p. L372) for the auxiliaries to curve forward in advance of the first saddle, as illustrated by Uhlig (1883, pl. 18, figs. 11–14), does not bar *Parasilesites* from that family considering that the tendency, as discussed by Fallot (1920*b*, p. 209) is general only among adults. The type species of *Parasilesites* is *P. bullatus* Imlay, n. sp.

PARASILESITES BULLATUS Imlay, n. sp.
Pl. 29, figs. 1–8

Only two specimens of this species are known. Whorls ovate in section, a little higher than wide, embracing about two-fifths. Flanks gently convex, rounding evenly into highly arched venter. Umbilicus fairly wide, shallow; umbilical wall low, steeply inclined, rounding evenly into flanks. Body chamber incomplete, represented by at least half a whorl.

The innermost whorls, exposed in the umbilicus of the type specimens, are marked by 7 or 8 deep, forwardly inclined constrictions and by faint forwardly inclined riblets. On the penultimate whorl the riblets are a little stronger and more flexuous, and number from 5 to 7 between successive constrictions. Those riblets adjoining constrictions are a little larger than the others and some of them bear weak bullae near the umbilical margin. On the body whorl both constrictions and ribs become stronger, many ribs are bullate, and some rib branching occurs at the bullae. On both the penultimate and body whorls, the ribs and constrictions arch forward on the venter and most of the ribs are somewhat weakened on the venter. The venter of the internal mold at the beginning of the body chamber bears a distinct groove that has a length of only 8 mm. The ribs end abruptly at this groove and some terminate in swellings. The groove may represent a deformity and probably is not of specific importance.

The suture line is very simple. Its auxiliaries descend only slightly toward the umbilical seam. The ventral lobe is nearly as long as the first lateral lobe.

The holotype at a dimeter of 27 mm. has a whorl height of 9 mm., a whorl thickness of 8 mm., and an umbilical width of 11.5 mm.

The species is characterized by developing distinct umbilical bullae, by having fairly regularly-spaced constrictions and ribs, and by some of the ribs bifurcating from the bullae. The small paratype resembles *Silesites puzosiaformis* Anderson (1938, p. 191, pl. 20, figs. 9,10) from the early Albian of California, but is stouter, has coarser ribbing, more and deeper constrictions, and bears weak umbilical bullae.

Types.—Holotype, USNM: 129872; paratype, USNM: 129873.

Occurrence.—USGS Mes. loc. 9492.

REFERENCES

ANDERSON, F. M., 1938, Lower Cretaceous deposits in California and Oregon: Geol. Soc. America Special Paper 16, 339 p., 85 pls., 6 text-figs.

BREISTROFFER, MAURICE, 1947, Zur les zones d'Ammonites dans l'Albien de France et d'Angleterre: Lab. Geol. Grenoble, v. 26, p. 1–88.

BRINKMANN, ROLAND, 1937, Biostratigraphie des Leymeriellenstammes nebst Bemerkungen zur Paläogeographie des Nordwestdeutschen Alb: Mitt. Geol. Staatinstitut in Hamburg., no. 16, p. 1–18, figs. 1–12.

CASEY, RAYMOND, 1954, New genera and subgenera of Lower Cretaceous ammonites: Wash. Acad. Sci. Jour., v. 44, no. 4, p. 106–115, 1 pl.

CHAPUT, M. E., 1920, Les Desmocératidés du Paléocrétacé. Revision du genre Desmoceras *in* KILIAN, WILFRED, *et al.* Contributions a l'étude des cephalopodes paléocrétacés du Sud-Est de la France: Mém. Carte géol. dét. France, p. 167–180, 1 pl.

COLLINGNON, MAURICE, 1949, Recherches sur les faunes Albiennes de Madagascar. I—L'Albien d'Ambarimaninga (Madagascar): Annales géol. Serv. des Mines de Madagascar, part. 16, 128 p., 22 pls., 29 text-figs.

FALLOT, PAUL, 1920*a*, La faune des marnes Aptiennes et albiennes de la region d'Andraitz, Majorque: Trab. Mus. Nac. de cienc. Nat., ser. geol., no. 26 (Madrid), p. 1–68, pls. 1–3.

——, 1920*b*, Remarques sur el genre Silesites *in* KILIAN, WILFRED, *et al.*, Contributions a l'étude des céphalopodes paléocrétacés du Sud-Est de la France: Mém. Carte géol. dét. France, p. 207–226, 7 text-figs.

HYATT, ALPHEUS, 1900, Cephalopoda: *in* ZITTEL, K. A., Textbook of Paleontology, 1st. English ed., transl. Eastman, C. R., p. 502–592, figs. 1049–1235.

KILIAN, WILFRED, 1907–1913, Unterkreide (Palaeocretacicum): *in* FRECH, F.,, Lethaea Geognostica, II, Mesozoicum, v. 3 (Kreide), 398 p., pls. 1–14.

KOENEN, A. von., 1902, Die Ammoniten des Norddeutschen Neocom (Valanginien, Hauterivian, Barremian und Aptien): Abh. preuss. geol. Landesanst., N. F., no. 34, 451, p., 55 pls.

MC LEARN, F. H., 1945, Revision of the Lower Cretaceous of the western interior of Canada: Geol. Survey Canada Paper 44–17 (2d ed.), 14 p., 2 tables, 12 pls.

——, 1948, New Lower Cretaceous species from Alberta and northeastern British Columbia: Appendix to Geol. Survey Canada Paper 44-17 2 p.

——, & KINDLE, E. D., 1950, Geology of northeastern British Columbia: Geol. Survey Canada Mem. 259, 236 p., 8 pls., 16 text-figs., 1 map, 6 tables.

MELLON, C. B., & WALL, J. H., 1956, Geology of the McMurray formation, Part. 1, Foraminifera of the upper McMurray and basal Clearwater formations: Research Council of Alberta Rept. no. 72. 29 p., 4 pls., 4 figs.

MOFFIT, F. H., 1938, Geology of the Chitina Valley and adjacent area Alaska: U. S. Geol. Survey, Bull. 894, 137 p., 16 pls., 1 map.

MURPHY, M. A., 1956, Lower Cretaceous stratigraphic units of northern California: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 9, p. 2098–2116, 6 figs.

SPATH, L. F., 1923–1943, A monograph of the Ammonoidea of the Gault: Palaeontogr. Soc., 2 v., 787 p., 72 pls., 248 text-figs., 4 tables.

——, 1927–1933, Revision of the Jurassic cephalopoda fauna of Kachh (Cutch): Pal. Indica, n. ser., v. 9, 6 pts., 945 p., 130 pls.

STELCK, C. R., 1958, Stratigraphic position of the Viking sand: Alberta Soc. Petroleum Geol., Jour., v. 6, no. 1, p. 2–7, 3 figs.

——, WALL, J. H., BAHAN, W. G., & MARTIN, L. J., 1956, Middle Albian foraminifera from Athabasca and Peace River Drainage area of western Canada: Research Council of Alberta Rept. no. 75, 60 p., 5 pls., 2 figs.

UHLIG, VICTOR, 1883, Die Cephalopodenfauna der Wernsdorfer Schichten: K. Akad. Wiss., Math.-naturh. Kl., Denks., v. 46, p. 1–166 (128–290), 32 pls.

WHITEAVES, J. F., 1889, On some Cretaceous fossils from British Columbia, the northwest territory and Manitoba: Geol. Survey Canada Contr. to Canadian Paleontology, v. 1, p. 151–196, pls. 20–24.

WOLLEMANN, A., 1907, Die Fauna des mittleren Gaults von Algermissen: Jahrb. Preuss. geol. Landesanstalt u. Bergakademie fur 1903, v. 24, p. 22–42, pls. 4,5.

WRIGHT, C. W., *in* ARKELL, W. J., KUMMEL, BERNHARD, & WRIGHT, C. W., 1957, Mesozoic Ammonoidea: Treatise on Invertebrate Paleontology, Part L, Mollusca 4, 490 p., illus.

MANUSCRIPT RECEIVED AUGUST 7, 1958.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 186–194, JANUARY 1959

GAMETANGIAL CONSTANTS OF EXTANT CHAROPHYTA FOR USE IN MICROPALEOBOTANY*

R. D. WOOD
Botany Department, University of Rhode Island, Kingston, Rhode Island

ABSTRACT—Descriptive data on extant species of Charophytes have been compiled, and from them are presented four tables for use in identifying fossils. In the tables, the species are arranged by increasing quantitative value of (1) maximum oogonium length, (2) maximum number of oogonial convolutions, (3) maximum oospore length, and (4) maximum number of oospore striae. They are intended to assist workers in reducing the number of possibilities in specific determinations to a relatively small number, thus reducing the burden of identification. The tables should be useful to micropaleobotanists and phycologists alike.

INTRODUCTION

IDENTIFICATION of fossil Charophyta of the modern type requires checking whether or not they belong to extant species. Since there are over 300 species currently recognized this is not easy. In order to develop a method by which workers could eliminate all but the most likely possibilites, the writer prepared a series of four tables containing gametangial characters of extant Characeae arranged in order of increasing quantitative values. Included are length of oogonium (or limeshell), number of convolutions of oogonium, length of oospore, and number of striae of oospore. The species included are those accepted by Wood (1952) augmented from Imahori (1954). See the former for a useful and concise listing. The data were taken from hand-sort punched cards containing species descriptions, by the method described earlier (Wood, 1957).

The data contained in the tables were originally extracted from the foremost taxonomic references. The majority of values were taken from the works of Braun (1867), Braun & Nordstedt (1882), Migula (1890, 1904, 1930), Robinson (1906), Groves & Bullock-Webster (1920, 1924), Zaneveld (1940), Wood (1948), Daily (1953), Imahori (1954), and Allen (1954). Data on new and unique species were gleaned from the many works of specialists such as Corillion, Filarszky, Hy, and Vilhelm. For more complete list of references, see the works of Wood (1952), Imahori (1954), and Groves & Bullock-Webster (1924).

Certain difficulties are inherent in the sources of information, and compromises are necessary in organizing the figures.—Oogonium length: Descriptions occasionally fail to specify whether the coronula was included in the measurement. An endeavor was made to determine the practice of each writer; however, where doubt remained, the uncertainty was indicated by "?." Where it is thought that the coronula was included, its length has been subtracted. When the size of the coronula was not known, an arbitrary 25μ was subtracted from the oogonium lengths of Nitelleae, and 50μ from those of the tribe Chareae.—Disagreements among available data: Where two foremost authors give somewhat different values, the combined range is used.—Data from illustrations: Where descriptions lack certain measurements, but where good plates are available, measurements have been taken from the figures.—Absence of data: Where no information is available, the species name is listed alphabetically at the end of the table.

Difficulties in arranging overlapping values were resolved by the following policy. Species were arranged in order of the maximum value of the feature. Within a group having the same maximum values, the ones with greatest range of variation were listed first, followed by those of lesser range.

Difficulties in taxonomy of extant Characeae require that the tables be used with certain reservations. No modern monograph covers all charophytes of the world. The most recent attempt is that by Braun and Nordstedt (1882). Subsequent studies

* Supported in part by the Research Fund of the College of Arts and Sciences of the University of Rhode Island; and in part by a grant G 2517 of the National Science Foundation, 1956–57.

TABLE 1.—EXTANT CHARACEAE IN ORDER OF INCREASING MAXIMUM OOGONIUM LENGTH

Length excludes coronula. Where reference author included coronula, its length has been subtracted; whereas, "?" indicates cases where that author's intent is uncertain.

Length (microns)	Species	Length (microns)	Species
220-190	*Nitella capillata*	?470-400	*Tolypella intricata*
220-190	*N. moniliformis*	470-435	*Nitella spinosa*
?240	*N. guineensis*	475-355	*N. flagelliformis*
245-225	*N. allenii*	?475-450	*Tolypella giennensis*
265–230	*N. lecheri*	477-247	*Nitella acuminata*
275–175	*Tolypella coutinhoi*	?480	*N. axillocarpa*
?276	*Nitella suspicata*	?485-430	*N. translucens*
280-240	*N. gracillima*	490-410	*N. robusta*
?284-257	*N. transilis*	490-460	*N. spiciformis*
286–258	*N. pseudotenuissima*	500-290	*N. tumulosa*
300–267	*N. bonaërensis*	500-375	*N. struthioptila*
?300	*N. habrocoma*	500-425	*N. divaricata*
310-225	*N. arechavaletae*	500-425	*Tolypella nidifica*
?325-275	*N. superba*	500-450	*Nitella vermiculata*
?325-285	*N. axillaris*	500	*N. blowiana*
325–285	*N. sublucens*	?500	*N. gracilis*
325	*N. globulifera*	500	*N. heteroteles*
327–227	*N. uruguayensis*	505-405	*N. multipartita*
?340	*N. plumosa*	?505	*N. baronii*
?350-330	*Chara morongii*	510-450	*N. saitoiana*
351–265	*Nitella morongii*	?510-450	*Tolypella prolifera*
355–316	*N. alleninda*	510-460	*Nitella tanakiana*
360-336	*Tolypella gracilis*	?513	*N. hyalina*
?365	*Nitella leibergii*	?515-415	*N. capitulifera*
370	*N. tenuissima*	515-415	*N. crispa*
375-350	*N. duthieae*	515-415	*N. dimorpha*
375-350	*N. grovesii*	515-465	*N. stricta*
390–350	*N. stabilis*	515-485	*N. tuyamae*
395-335	*N. capitellata*	?520-450	*Chara curtissii*
400-340	*N. sumatrana*	525-425	*Tolypella palhinhae*
400-370	*N. axilliformis*	?525-450	*Nitella dixonii*
405-335	*N. expansa*	?530-354	*N. oligospira*
?405-380	*N. praeclara*	530-430	*N. shinii*
?405	*N. tumida*	?530-480	*Chara abnormiformis*
410-355	*N. erecta*	?530	*C. longifolia(?)*
?415	*N. dictyosperma*	?535-525	*Nitella remota*
420-370	*N. phauloteles*	?540-505	*N. mucronata*
420-400	*N. bengalensis*	?541	*Chara keukensis*
?425-375	*N. ornithopoda*	545	*C. inermis*
425-405	*N. gracilens*	?550-320	*C. sibirica*
425	*N. ogivalis*	550-450	*Nitella japonica*
?430-330	*N. coreana*	550-475	*N. sphaerocephala*
?433-383	*Chara hatei*	?550-500	*Chara mollusca*
435-355	*Nitella lhotzkyi*	550-500	*Nitella pusilla*
?435-360	*N. confervacea*	?550-520	*Chara coronatiformis*
435-385	*N. inaequalis*	?550-525	*Nitella capillaris*
435-410	*N. madagascariensis*	?555-475	*N. syncarpa*
?440-416	*Chara pelosiana*	?555-485	*Chara conimbrigensis*
445-373	*Nitella bipartita*	?560-440	*C. cubensis*
450-220	*N. microcarpa*	560-460	*Nitella flagellifera*
?450-400	*N. doidgeae*	560	*Chara erythrogyna*
450-410	*N. oligogyra*	?560	*C. hypnoides*
450-420	*N. inversa*	560	*Nitella sejuncta*
?460-400	*N. musasiensis*	565-465	*N. rigida*
460-410	*N. graciliformis*	?570-530	*Chara schaffneri*
460-410	*N. pulchella*	?575-555	*Tolypella longicoma*
?465-395	*Tolypella glomerata*	?580-480	*Nitella moriokae*
470-400	*Nitella horikawae*	580-535	*N. tuberculata*

TABLE 1.—(*Continued*)

Length (microns)	Species	Length (microns)	Species
?600	*Chara fischeri*	?790-740	*Nitella spanioclema*
?610-600	*C. pistianensis*	?790-660	*Chara palmeri*
610	*C. succincta*	800-525	*C. vulgaris*
?615-525	*C. pashanii*	800-600	*C. aspera*
?620-540	*C. infirma*	800-700	*C. muscosa*
625-576	*Nitella conifera*	810-530	*C. contraria*
?645-375	*Chara rusbyana*	?810-610	*C. papillosa*
650-440	*C. gymnopitys*	?810-770	*C. leiopitys*
?650-500	*C. tenuispina*	?820-640	*C. bohemica*
?650	*C. baueri*	?840-730	*C. filicaulis*
655-255	*Nitella furcata*	850-550	*C. canescens*
655-555	*N. fallosa*	?850-650	*C. strigosa*
660-640	*Chara arcuatofolia*	?850-770	*C. brittonii*
?657	*Tolypella comosa*	?850-800	*Lamprothamnium toletanus*
?670-550	*Chara altaica*	?850	*Chara socotrensis*
?670-650	*C. leptosperma*	855-665	*C. zeylanica*
?670	*C. braunii*	?860-585	*Nitella flexilis*
?670	*C. tanyglochis*	?860-660	*Chara sanctae-margaritae*
?675-425	*C. arrudensis*	860-700	*C. wallichii*
?675-625	*Nitella opaca*	?860-820	*C. formosa*
?680-595	*Chara brachypus*	?865-685	*Protochara australis*
?685-625	*Tolypella apiculata*	?880-580	*Chara pallida*
685	*Nitella megacarpa*	?880	*C. globata*
700-300	*Chara hydropitys*	900-790	*C. concinna*
?700-500	*Nitella knightiae*	900	*C. fulgens*
700-600	*Chara chrysospora*	910-730	*C. australis*
700-600	*C. pseudo-brachypus*	?910-750	*C. hirsuta*
700-660	*Nitella monodactyla*	?910-810	*C. intumescens*
?700	*Chara fibrosa*	925-625	*C. globularis*
?700	*C. grovesii*	950-650	*C. connivens*
?700	*C. hansenii*	950-750	*Lamprothamnium papulosum*
?700	*C. oedophylla*	?950-800	*Chara galioides* (?)
700	*C. submollusca*	960-750	*C. delicatula*
?710	*C. mauretanica*	?970-850	*Lamprothamnium aragonensis*
?725-425	*Tolypella hispanica*	?1000-810	*Chara inconnexa*
?730	*Chara kieneri*	1000-875	*C. fragifera*
?730	*C. nuda*	1000	*C. baltica*
750-625	*C. desmacantha*	1000	*C. buckellii*
?750-700	*C. crinitiformis*	1000	*C. tomentosa*
?750-700	*C. schroederi*	?1050-900	*C. nordhoffiae*
?750-710	*C. gobiana*	?1070-910	*C. compacta*
?750	*C. filiformis*	1100-850	*C. aculeolata*
?755-705	*Nitella praelonga*	1100-1000	*C. denudata*
?760	*Chara domini*	1100-1000	*C. hispida*
770	*C. handae*	?1125-825	*C. hornemannii*
?773	*Tolypella fimbriata*	?1140-840	*C. sejuncta*
?775-675	*Nitella laxa*	?1230-925	*C. corallina*
?780-620	*Chara evoluta*	?1335-1135	*Nitellopsis obtusa*

Data not available for following species: *Chara amplexa, C. brionica, C. burmanica, C. capensis, C. corfuensis, C. disjuncta, C. drummondii, C. ecklonii, C. excelsa, C. hereroensis, C. hippelliana, C. hungarica, C. imperfecta, C. javanica, C. kenoyeri, C. kirghisorum, C. kraussiana, C. lamyana, C. leptopitys, C. mucronata* [nom illeg.], *C. myriophylla, C. phaeochiton, C. poopoensis, C. salina, C. scepusiensis, C. stachymorpha, C. tenera, C. verticulata—Lamprothamnium macropogon—Lychnothamnus barbatus—Nitella abyssinica, N. annadalei, N. anomala, N. asagrayana, N. bastinii, N. blankinshipii, N. brachyteles, N. burmanica, N. californica, N. cernua, N. clavata, N. comptonii, N. conformis, N. congesta, N. cristata, N. diffusa, N. dilatata, N. dregeana, N. dualis, N. elegans, N. fascicularis, N. gelatinosa, N. gloeostachys, N. havaiensis, N. heterodactyla, N. heterophylla, N. hookeri, N. intermedia, N. leonhardii, N. leptoclada, N. leptodactyla, N. leptosoma, N. leptostachys, N. longifurca, N. macounii, N. mauritiana, N. mexicana, N. microphylla, N. minuta, N. mirabilis, N. missouriensis, N. montana, N. muthnatae, N. myriotricha, N. obtusa, N. occidentalis, N. orientalis, N. partita, N. patula, N. paucicostata, N. penicillata, N. polycarpa, N. polycephala, N. polygyra, N. pseudoflabellata, N. pygmaea, N. robertsonii, N. sonderi, N. stellaris, N. stuartii, N. subtilissima, N. tasmanica, N. tricellularis, N. wattii, N. zeyheri—Nitellopsis aculeolata, N. sarcularis—Protochara inflata—Tolypella californica, T. intertexta, T. stipitata.*

TABLE 2.—EXTANT CHARACEAE IN ORDER OF INCREASING MAXIMUM NUMBER OF OOGONIAL CONVOLUTIONS

Convolutions	Species	Convolutions	Species	Convolutions	Species
3–5	*Nitella bonaërensis*	8	*N. tuyamae*	9	*N. praeclara*
4–6	*N. gracilens*	7–9	*Chara australis*	9	*N. tenuissima*
5–6	*N. moniliformis*	7–9	*C. corallina*	9	*Nitellopsis obtusa*
5–6	*N. oligogyra*	7–9	*Nitella bengalensis*	8–10	*Chara baueri*
5–6	*N. zeyheri*	7–9	*N. opaca*	8–10	*C. fibrosa*
6–7	*N. bipartita*	8–9	*N. acuminata*	8–10	*C. pashanii*
6–7	*N. erecta*	8–9	*N. arechavaletae*	8–10	*Nitella horikawae*
6–7	*N. musasiensis*	8–9	*N. axilliformis*	8–10	*N. lechleri*
6–7	*N. penicillata*	8–9	*N. confervacea*	8–10	*N. pusilla*
6–7	*Protochara australis*	8–9	*N. crispa*	8–10	*N. robusta*
6–7	*Tolypella coutinhoi*	8–9	*N. dimorpha*	9–10	*Chara conimbrigensis*
7	*Nitella allenii*	8–9	*N. diodgeae*	9–10	*C. corfuensis*
7	*N. axillaris*	8–9	*N. expansa*	9–10	*C. erythrogyna*
7	*N. axillocarpa*	8–9	*N. flagelliformis*	9–10	*Nitella capitulifera*
7	*N. capillaris*	8–9	*N. flexilis*	9–10	*N. divaricata*
7	*N. shinii*	8–9	*N. furcata*	9–10	*N. globulifera*
7	*N. spanioclema*	8–9	*N. graciliformis*	9–10	*N. gloeostachys*
6–8	*N. madagascariensis*	8–9	*N. gracilis*	9–10	*N. microphylla*
6–8	*N. spiciformis*	8–9	*N. grovesii*	9–10	*N. ornithopoda*
6–8	*N. tumulosa*	8–9	*N. japonica*	9–10	*N. spinosa*
7–8	*Chara wallichii*	8–9	*N. laxa*	9–10	*N. stricta*
7–8	*Nitella alleninda*	8–9	*N. multipartita*	9–10	*N. struthioptila*
7–8	*N. coreana*	8–9	*N. pseudotenuissima*	9–10	*Tolypella comosa*
7–8	*N. fallosa*	8–9	*N. pulchella*	9–10	*T. glomerata*
7–8	*N. gracillima*	8–9	*N. sejuncta*	9–10	*T. gracilis*
7–8	*N. microcarpa*	8–9	*N. stabilis*	10	*Chara leptopitys*
7–8	*N. monodactyla*	8–9	*N. sublucens*	10	*C. mollusca*
7–8	*N. moriokae*	8–9	*N. subtilissima*	10	*Nitella conifera*
7–8	*N. mucronata*	8–9	*N. sumatrana*	10	*Tolypella nidifica*
7–8	*N. oligospira*	8–9	*N. superba*	10	*T. palhinae*
7–8	*N. paucicostata*	8–9	*N. tanakiana*	9–11	*Chara gymnopitys*
7–8	*N. rigida*	9	*Chara hatei*	10–11	*C. schroederi*
7–8	*N. saitoiana*	9	*Nitella baronii*	10–11	*Lamprothamnium toletanus*
7–8	*N. syncarpa*	9	*N. flagellifera*	10–11	*Nitella dixonii*
7–8	*N. transilis*	9	*N. habrocoma*	11	*Chara drummondii*
7–8	*N. translucens*	9	*N. heteroteles*	11	*C. gobiana*
7–8	*N. uruguayensis*	9	*N. knightiae*	11	*C. keukensis*
8	*N. hyalina*	9	*N. lhotzkyi*	11	*Lamprothamnium macropogon*
8	*N. inversa*	9	*N. megacarpa*		
8	*N. ogivalis*	9	*N. polygyra*		

(*Concluded on next page*)

Data not available for following species: *Chara abnormiformis, C. amplexa, C. arcuatofolia, C. arrudensis, C. brittonii, C. buckellii, C. burmanica, C. capensis, C. compacta, C. coronatiformis, C. crinitiformis, C. cubensis, C. curtissii, C. disjuncta, C. domini, C. ecklonii, C. evoluta, C. excelsa, C. filicaulis, C. formosa, C. fulgens, C. galioides, C. hereroensis, C. hippelliana, C. hirsuta, C. hornemannii C. hungarica, C. hypnoides, C. imperfecta, C. inconnexa, C. infirma, C. intumescens, C. kenoyeri, C. kirghisorum, C. kraussiana, C. lamyana, C. leiopitys, C. leptosperma, C. longifolia, C. morongii, C. mucronata, C. myriophylla, C. nordhoffiae, C. pallida, C. palmeri, C. pelosiana, C. phaeochiton, C. poopoensis, C. rusbyana, C. salina, C. sanctae-margaritae, C. scepusiensis, C. schaffneri, C. sejuncta, C. sibirica, C. stachymorpha, C. strigosa, C. submollusca, C. tanyglochis, C. verticulata—Lamprothamnium aragonensis—Lychnothamnus barbatus—Nitella abyssinica, N. annandalei, N. annularis, N. anomala, N. asagrayana, N. bastini, N. blankinshipii, N. blowiana, N. brachyteles, N. burmanica, N. californica, N. capillata, N. capitellata, N. cernua, N. clavata, N. comptonii, N. conformis, N. congesta, N. cristata, N. dictyosperma, N. diffusa, N. dilatata, N. dregeana, N. dualis, N. duthieae, N. elegens, N. fascicularis, N. gelatinosa, N. guineensis, N. havaiensis, N. heterodactyla, N. heterophylla, N. hookeri, N. inaequalis, N. intermedia, N. leibergii, N. leonhardii, N. leptoclada, N. leptodactyla, N. leptosoma, N. leptostachys, N. longifurca, N. macounii, N. mauretiana, N. mexicana, N. minuta, N. mirabilis, N. missouriensis, N. montana, N. morongii, N. muthnatae, N. myriotricha, N. obtusa, N. occidentalis, N. orientalis, N. partita, N. patula, N. phauloteles, N. plumosa, N. polycarpa, N. polycephala, N. praelonga, N. pseudoflabellata, N. pygmaea, N. remota, N. robertsonii, N. sonderi, N. sphaerocephala, N. stellaris, N. stuartii, N. subspicata, N. tasmanica, N. tricellularis, N. tuberculata, N. tumida, N. vermiculata, N. wattii—Nitellopsis aculeolata, N. sarcularis—Tolypella californica, T. giennensis, T. hispanica, T. intertexta, T. longicoma, T. stipitata.*

TABLE 2.—(*Continued*)

Convolutions	Species	Convolutions	Species	Convolutions	Species
11	*Tolypella fimbriata*	11–14	*C. hydropitys*	13–15	*C. brachypus*
10–12	*Chara oedophylla*	11–14	*C. pseudo-brachypus*	13–15	*C. canescens*
10–12	*C. tenera*	12–14	*C. fragifera*	13–15	*C. contraria*
11–12	*C. inermis*	12–14	*C. papillosa*	13–15	*C. denudata*
11–12	*C. javanica*	13–14	*C. concinna*	14–15	*C. baltica*
11–12	*C. socotrensis*	13–14	*C. connivens*	14–15	*C. delicatula*
11–12	*C. succincta*	13–14	*C. hispida*	14–15	*C. grovesii*
11–12	*Tolypella prolifera*	14	*C. bohemica*	14–15	*C. mauretanica*
12	*Chara altaica*	14	*C. fischeri*	14–15	*Protochara inflata*
12	*Tolypella apiculata*	14	*C. nuda*	15	*Chara tomentosa*
8–13	*Chara braunii*	12–15	*C. aculeolata*	13–16	*C. vulgaris*
10–13	*Tolypella intricata*	12–15	*C. filiformis*	15–16	*C. handae*
12–13	*Chara chrysospora*	12–15	*C. tenuispina*	14–17	*C. desmacantha*
12–13	*C. hansenii*	12–15	*C. zeylanica*	14–17	*C. globularis*
12–13	*C. kieneri*	12–15	*Lamprothamnium papulosum*	14–17	*C. muscosa*
12–13	*C. pistianensis*			16–18	*C. globata*
13	*C. brionica*	13–15	*Chara aspera*		

TABLE 3.—EXTANT CHARACEAE IN ORDER OF INCREASING MAXIMUM OOSPORE LENGTH

Length (microns)	Species	Length (microns)	Species	Length (microns)	Species
188	*Nitella pseudotenuissima*	272	*N. leibergii*	320-270	*N. spiciformis*
200-180	*N. sonderi*	275-210	*N. macounii*	320-290	*N. axillaris*
200	*N. habrocoma*	275	*N. mexicana*	320-290	*N. japonica*
213	*N. bipartita*	280-250	*N. axilliformis*	320-300	*N. inversa*
220-180	*N. gracillima*	280-250	*Tolypella giennensis*	320-300	*N. microphylla*
220-200	*N. allenii*	280-260	*Nitella gracilens*	320-300	*N. pseudoflabellata*
220	*N. elegans*	280-270	*N. tumida*	320	*Chara morongii*
221	*N. capillata*	280	*N. annularis*	320	*Nitella dixonii*
222-200	*N. lechleri*	280	*N. dictyosperma*	325-260	*N. graciliformis*
225-180	*N. moniliformis*	280	*N. ogivalis*	325-272	*N. asagrayana*
225-200	*N. wattii*	285-265	*N. muthnatae*	325-275	*N. madagascariensis*
225	*N. supspicata*	285-272	*N. transilis*	325-300	*N. heteroteles*
228	*N. leptodactyla*	290-260	*N. horikawae*	325	*Chara hatei*
240-220	*N. tasmanica*	290-265	*N. inaequalis*	330-280	*Nitella coreana*
240-230	*N. stellaris*	300-200	*N. gloeostachys*	330-280	*N. moriokae*
240	*N. leptoclada*	300-225	*N. confervacea*	330-280	*N. rigida*
240	*N. subtilissima*	300-225	*Tolypella hispanica*	330-290	*N. musasiensis*
249-237	*N. alleninda*	300-250	*Nitella gracilis*	330-300	*N. flagellifera*
250-200	*N. tenuissima*	300-250	*N. ornithopoda*	330-300	*N. pusilla*
250-200	*N. stuartii*	300-260	*Tolypella gracilis*	330-300	*N. spinosa*
250-230	*N. capitellata*	300-265	*Nitella bastini*	330	*N. blowiana*
250-230	*N. oligogyra*	300-270	*N. dimorpha*	335-250	*N. hyalina*
250-240	*N. dregeana*	300-275	*N. divaricata*	335-263	*N. sumatrana*
250-240	*N. plumosa*	300-275	*N. doidgeae*	335-300	*Tolypella stipitata*
250	*N. duthieae*	300-275	*N. phauloteles*	340-275	*Nitella acuminata*
250	*N. pygmaea*	300-275	*N. praeclara*	340-290	*N. capitulifera*
255-240	*N. grovesii*	300-280	*N. shinii*	340	*N. baronii*
260-180	*N. dualis*	300-280	*N. stabilis*	345	*N. tuberculata*
260-250	*N. myriotricha*	300-280	*N. tanakiana*	350-270	*N. saitoiana*
260-250	*N. penicillata*	300-280	*N. tuyamae*	350-285	*N. minuta*
260	*N. polycarpa*	300-290	*N. lhotzkyi*	350-400	*N. mucronata*
260-238	*N. morongii*	300	*N. burmanica*	350-300	*N. orientalis*
270-200	*N. arechavaletae*	300	*N. comptonii*	350-300	*N. syncarpa*
270-200	*N. gelatinosa*	300	*N. sejuncta*	350-300	*N. vermiculata*
270-235	*N. uruguayensis*	300	*Tolypella palhinhae*	350-302	*N. flagelliformis*
270-240	*N. bengalensis*	310-220	*Nitella erecta*	350-310	*N. leptosoma*
270-250	*N. expansa*	310-280	*N. sublucens*	350-320	*N. stricta*
		320-260	*N. pulchella*	350-325	*N. translucens*

TABLE 3.—(*Continued*)

Length (microns)	Species
350-330	*N. crispa*
350	*N. axillocarpa*
350	*N. diffusa*
360-260	*N. multipartita*
360	*N. intermedia*
360	*N. leonhardii*
370-350	*Characoronatiformis*
375-300	*Tolypella glomerata*
375-325	*Nitella struthioptila*
375	*N. patula*
380-285	*Tolypella californica*
380-300	*Nitella cristata*
390-345	*N. occidentalis*
400-190	*N. furcata*
400-245	*N. tumulosa*
400-260	*N. oligospira*
400-320	*Tolypella intricata*
400-325	*Nitella capillaris*
400-325	*N. sphaerocephala*
400-330	*Tolypella prolifera*
400-340	*Nitella havaiensis*
400-350	*N. robusta*
400-360	*Tolypella longicoma*
400-375	*Nitella missouriensis*
400	*Chara erythrogyna*
410-360	*Nitella fallosa*
420-400	*Chara curtissii*
420-400	*C. mollusca*
420	*Nitella megacarpa*
425-375	*N. opaca*
425	*N. hookeri*
430-330	*Chara leptopitys*
430-360	*C. conimbrigensis*
430-370	*Nitella brachyteles*
440-400	*N. paucicostata*
440	*Chara hypnoides*
440	*Nitella montana*
445-400	*Chara pashanii*
450-180	*Nitella microcarpa*
450-400	*N. congesta*
450-425	*N. conifera*
450-425	*Tolypella fimbriata*
450	*Chara inermis*
450	*C. longifolia*
450	*C. nuda*
450	*C. oedophylla*
450	*Nitella blankinshipii*
460-420	*Chara cubensis*
460	*C. schaffneri*
460	*Nitella obtusa*
470-300	*N. clavata*
470-400	*N. tricellularis*
470-430	*N. remota*
475-375	*N. mirabilis*
475-400	*Tolypella nidifica*
475-425	*T. comosa*
475-450	*T. intertexta*
480-440	*Nitella dilatata*
480-440	*N. monodactyla*
480-450	*Chara altaica*
480-450	*C. pistianensis*
480	*C. sibirica*
490-440	*C. keukensis*
500-375	*C. chrysospora*
500-450	*C. arrudensis*
500-475	*Nitella spanioclema*
500-480	*Tolypella apiculata*
500	*Chara drummondii*
500	*C. fischeri*
510-470	*C. crinitiformis*
520-420	*C. pallida*
520-450	*C. tenuispina*
520	*C. socotrensis*
525-400	*Nitella knightiae*
525	*Chara desmacantha*
530-280	*C. hydropitys*
530-450	*C. hippelliana*
535-500	*Nitella californica*
535	*Chara succincta*
550-350	*C. fibrosa*
550-500	*C. baueri*
550-500	*C. hansenii*
550	*C. mauretanica*
560-490	*Protochara australis*
560-540	*Nitella praelonga*
560	*Chara schroederi*
570-360	*C. submollusca*
575-500	*Nitella flexilis*
580	*Chara gobiana*
587-537	*C. hungarica*
600-450	*Nitella laxa*
600-475	*Chara pseudo-brachypus*
600-500	*C. galioides*
600-540	*C. capensis*
600-540	*C. concinna*
600-540	*C. inconnexa*
600-550	*C. leptosperma*
600(?)	*C. leiopitys*
610-500	*C. wallichii*
615	*C. handae*
620-510	*Nitella cernua*
625-350	*Chara canescens*
630-560	*C. intumescens*
630	*C. ecklonii*
636-450	*C. kieneri*
650-330	*C. gymnopitys*
650-400	*C. aspera*
650-500	*C. brionica*
650-500	*C. phaeochiton*
650-600	*C. brittonii*
660-500	*C. filiformis*
660	*C. imperfecta*
665-615	*C. muscosa*
675-425	*C. vulgaris*
675-475	*C. amplexa*
680-580	*C. evoluta*
680-630	*C. hirsuta*
680-630	*C. sanctae-margaritae*
700-500	*C. globularis*
700-500	*C. strigosa*
700-550	*C. fragifera*
700-580	*C. connivens*
700-600	*C. stachymorpha*
700-600	*Lamprothamnium aragonensis*
700	*Chara baltica*
700	*C. burmanica*
700	*C. hereroensis*
710-650	*C. zeylanica*
720-500	*C. contraria*
720-600	*C. nordhoffiae*
720-625	*C. delicatula*
720-660	*Lychnothamnus barbatus*
725-575	*Chara kraussiana*
750-425	*C. braunii*
750-540	*C. excelsa*
750-600	*Lamprothamnium papulosum*
750-630	*Chara filicaulis*
750-700	*C. bohemica*
750-700	*C. hispida*
760-560	*C. brachypus*
770-730	*C. compacta*
775	*Nitellopsis obtusa*
780-760	*Chara arcuatofolia*
800-550	*C. australis*
800-560	*C. hornemannii*
800-650	*C. aculeolata*
800	*C. buckellii*
800	*C. globata*
820-660	*C. papillosa*
820-750	*C. formosa*
825-675	*C. denudata*
875-645	*C. corallina*
875-800	*C. tomentosa*
900	*C. domini*
910-660	*C. sejuncta*

Data not available for following species: *Chara abnormiformis, C. corfuensis, C. disjuncta, C. fulgens, C. grovesii, C. infirma, C. javanica, C. kenoyeri, C. kirghisorum, C. lamyana, C. mucronata, C. myriophylla, C. palmeri, C. pelosiana, C. poopoensis, C. rusbyana, C. salina, C. scepusiensis, C. tanyglochis, C. tenera, C. verticulata—Lamprothamnium macropogon, L. toletanus—Nitella abyssinica, N. annandalei, N. anomala, N. bonaërensis, N. conformis, N. fascicularis, N. globulifera, N. guineensis, N. heterodactyla, N. heterophylla, N. leptostachys, N. longifurca, N. mauritiana, N. partita, N. polygyra, N. robertsonii, N. superba, N. zeyheri—Nitellopsis aculeolata, N. sarcularis—Protochara inflata—Tolypella coutinhoi.*

TABLE 4.—EXTANT CHARACEAE IN ORDER OF INCREASING MAXIMUM NUMBER OF OOSPORE STRIAE

Striae	Species
4	*Nitella shinii*
4–5	*N. gracilens*
4–5	*N. moniliformis*
4–5	*N. paucicostata*
4–5	*Protochara australis*
5	*Nitella allenii*
5	*N. annularis*
5	*N. capitellata*
5	*N. mexicana*
5	*N. morongii*
5	*N. muthnatae*
5	*N. oligogyra*
5	*N. polycephala*
5–6	*N. asagrayana*
5–6	*N. bipartita*
5–6	*N. erecta*
5–6	*N. expansa*
5–6	*N. gracillima*
5–6	*N. guineensis*
5–6	*N. longifurca*
5–6	*N. megacarpa*
5–6	*N. monodactyla*
5–6	*N. moriokae*
5–6	*N. musasiensis*
5–6	*N. pusilla*
5–6	*N. rigida*
5–6	*N. saitoiana*
5–6	*N. spiciformis*
5–6	*N. stellaris*
5–6	*N. tanakiana*
5–6	*N. tumulosa*
5–6	*Tolypella coutinhoi*
6	*Nitella alleninda*
6	*N. axillaris*
6	*N. axillocarpa*
6	*N. bengalensis*
6	*N. brachyteles*
6	*N. burmanica*
6	*N. capillaris*
6	*N. cristata*
6	*N. curtissii*
6	*N. dictyosperma*
6	*N. dimorpha*
6	*N. havaiensis*
6	*N. laxa*
6	*N. leibergii*
6	*N. leptoclada*
6	*N. microcarpa*
6	*N. minuta*
6	*N. mirabilis*
6	*N. missouriensis*
6	*N. occidentalis*
6	*N. plumosa*
6	*N. pseudotenuissima*
6	*N. spanioclema*
6	*N. stricta*
6	*N. stuartii*
6	*N. subspicata*
6	*N. syncarpa*
6	*N. translucens*
5–7	*Chara hornemanii*
5–7	*C. nordhoffiae*
5–7	*C. pallida*
5–7	*Nitella axilliformis*
5–7	*N. duthieae*
5–7	*N. flexilis*
5–7	*N. furcata*
5–7	*N. gracilis*
5–7	*N. madagascariensis*
5–7	*N. phauloteles*
6–7	*Chara corallina*
6–7	*C. pashanii*
6–7	*C. wallichii*
6–7	*Nitella blankinshipii*
6–7	*N. californica*
6–7	*N. capitulifera*
6–7	*N. clavata*
6–7	*N. coreana*
6–7	*N. crispa*
6–7	*N. dilatata*
6–7	*N. dregeana*
6–7	*N. fallosa*
6–7	*N. hyalina*
6–7	*N. inversa*
6–7	*N. japonica*
6–7	*N. mucronata*
6–7	*N. ogivalis*
6–7	*N. oligospira*
6–7	*N. penicillata*
6–7	*N. polycarpa*
6–7	*N. praelonga*
6–7	*N. pseudoflabellata*
6–7	*N. robusta*
6–7	*N. sejuncta*
6–7	*N. sublucens*
6–7	*N. sumatrana*
7	*Chara crinitiformis*
7	*C. fibrosa*
7	*C. submollusca*
7	*Nitella flagellifera*
7	*N. grovesii*
7	*N. habrocoma*
7	*N. horikawae*
7	*N. inaequalis*
7	*N. leonhardii*
7	*N. lhotzkyi*
7	*N. multipartita*
7	*N. obtusa*
7	*N. opaca*
7	*N. patula*
7	*N. pygmaea*
7	*N. spinosa*
7	*N. stabilis*
7	*N. tuyamae*
7	*N. uruguayensis*
7	*Nitellopsis obtusa*
7	*Tolypella glennensis*
6–8	*Nitella acuminata*
6–8	*N. cernua*
6–8	*N. confervacea*
6–8	*N. flagelliformis*
6–8	*N. graciliformis*
7–8	*Chara australis*
7–8	*C. leptopitys*
7–8	*C. morongii*
7–8	*Nitella anomala*
7–8	*N. bastini*
7–8	*N. doidgeae*
7–8	*N. elegans*
7–8	*N. gelatinosa*
7–8	*N. leptodactyla*
7–8	*N. leptosoma*
7–8	*N. macounii*
7–8	*N. montana*
7–8	*N. myriotricha*
7–8	*N. ornithopoda*
7–8	*N. pulchella*
7–8	*N. struthioptila*
7–8	*N. tenuissima*
7–8	*N. transilis*
7–8	*N. tricellularis*
7–8	*N. tuberculata*
7–8	*N. tumida*
7–8	*N. vermiculata*
7–8	*N. wattii*
7–8	*Tolypella glomerata*
7–8	*T. gracilis*
7–8	*T. hispanica*
7–8	*T. stipitata*
8	*Chara baueri*
8	*C. conimbrigensis*
8	*C. coronatiformis*
8	*C. hypnoides*
8	*Lamprothamnium aragonensis*
8	*L. toletanus*
8	*Nitella blowiana*
8	*N. comptonii*
8	*N. conifera*
8	*N. diffusa*
8	*N. divaricata*
8	*N. heteroteles*
8	*N. intermedia*
8	*N. knightiae*
8	*N. praeclara*
8	*N. remota*
8	*N. sphaerocephala*
8	*Tolypella palhinhae*
7–9	*Chara oedophylla*
7–9	*Nitella arechavaletae*
7–9	*N. hookeri*
7–9	*N. orientalis*
7–9	*Tolypella comosa*
7–9	*T. nidifica*
8–9	*Chara erythrogyna*
8–9	*Nitella capillata*
8–9	*N. dixonii*
8–9	*Tolypella californica*
9	*Nitella congesta*
9	*N. lechleri*
9	*Tolypella longicoma*
9	*T. prolifera*
8–10	*Chara inconnexa*
8–10	*C. strigosa*
9–10	*C. capensis*
9–10	*C. inermis*
9–10	*C. schroederi*
9–10	*C. succincta*
9–10	*Tolypella fimbriata*

TABLE 4.—(*Continued*)

Striae	Species	Striae	Species	Striae	Species
10	*Chara buckellii*	11–12	*C. leptosperma*	12–14	*C. denudata*
10	*C. ecklonii*	12	*C. fischeri*	12–14	*C. filicaulis*
10	*C. imperfecta*	12	*C. nuda*	12–14	*C. filiformis*
10	*Tolypella apiculata*	9–13	*C. hydropitys*	13–14	*C. baltica*
10	*T. intertexta*	10–13	*C. canescens*	13–14	*C. sanctae-margaritae*
9–11	*Chara gymnopitys*	10–13	*C. intumescens*	14	*C. arcuatofolia*
9–11	*C. keukensis*	10–13	*C. pseudo-brachypus*	14	*C. brittonii*
9–11	*Tolypella intricata*	11–13	*C. galioides*	14	*C. domini*
10–11	*Chara altaica*	11–13	*C. handae*	14	*C. tomentosa*
10–11	*C. hansenii*	12–13	*C. bohemica*	11–15	*C. amplexa*
10–11	*C. palmeri*	12–13	*C. brachypus*	11–15	*C. excelsa*
11	*C. papillosa*	12–13	*C. connivens*	11–15	*C. stachymorpha*
11	*Lamprothamnium papulosum*	12–13	*C. hispida*	12–15	*C. arrudensis*
		13	*C. hereroensis*	12–15	*C. globularis*
7–12	*Chara braunii*	13	*C. kraussiana*	12–15	*C. sejuncta*
8–12	*C. phaeochiton*	13	*C. mauretanica*	12–15	*C. vulgaris*
9–12	*C. fragifera*	10–14	*C. contraria*	14–15	*C. hirsuta*
10–12	*C. compacta*	10–14	*C. keineri*	14–15	*C. leiopitys*
10–12	*C. evoluta*	11–14	*C. aculeolata*	15	*C. globata*
10–12	*C. zeylanica*	11–14	*C. tenuispina*	13–16	*C. desmacantha*
11–12	*C. burmanica*	12–14	*C. aspera*	13–16	*C. muscosa*
11–12	*C. chrysospora*	12–14	*C. cubensis*	14–16	*C. formosa*
11–12	*C. concinna*	12–14	*C. delicatula*	15–16	*C. tanyglochis*

Data not available for following species: *Chara abnormiformis, C. brionica, C. corfuensis, C. disjuncta, C. drummondii, C. fulgens, C. gobiana, C. grovesii, C. hatei, C. hippelliana, C. hungarica, C. infirma, C. javanica, C. kenoyeri, C. kirghisorum, C. lamyana, C. longifolia, C. mollusca, C. mucronata, C. myriophylla, C. pelosiana, C. pistianensis, C. poopoensis, C. rusbyana, C. salina, C. scepusiensis, C. schaffneri, C. sibirica, C. socotrensis, C. tenera, C. verticulata—Lamprothamnium macropogon—Lychnothamnus barbatus—Nitella abyssinica, N. annandalei, N. baronii, N. bonaërensis, N. conformis, N. dualis, N. fascicularis, N. globulifera, N. gloeostachys, N. heterodactyla, N. heterophylla, N. leptostachys, N. mauretiana, N. microphylla, N. partita, N. penicillata, N. polygyra, N. robertsonii, N. sonderi, N. subtilissima, N. superba, N. tasmanica, N. zeyheri—Nitellopsis aculeolata, N. sarcularis—Protochara inflata*

vary widely in caliber and point of view. Some authors are lumpers and others are splitters. Numerous newly described species have not as yet been evaluated. A reconciliation of these inconsistencies is needed, and has not been accomplished. Such defects must be recognized, and the tables handled with an element of caution.

USE OF THE TABLES

In identification of an unknown gametangium, fossil or extant, it is presumed that the worker will have determined the main features of a series of specimens (limeshells or oogonia). First, whether they are compressed (genus *Nitella*) or round in cross section is ascertained. Then, measurements are obtained of the range in length of limeshell (or oogonium), in number of oogonia convolutions, in length of oospore, and in number of oospore striae. The position of each can be found in the respective tables, as well as the various species which could fit the measurements obtained. All other species are thus eliminated. Where complete data are available and all four tables are employed, retaining only those species which fit in all four tables, the writer has found that all but 1–3 names are usually eliminated. The few remaining possibilities can then be subjected by critical examination for final identification.

LITERATURE CITED

ALLEN, G. O., 1954, An annotated key to the Nitelleae of North America: Bull. Torrey Bot. Club, v. 81, p. 35–60.

BRAUN, A., 1867, Die Characeen Afrika's: Monatsber. K. Akad. Wiss. Berlin, v. for 1867, p. 782–800, 873–944.

——, & NORDSTEDT, C. F. O., 1882, Fragmente einer Monographie der Characeen: Abh. K. Akad. Wiss. Berlin, v. for 1882, p. 1–211.

DAILY, FAY K., 1953, The Characeae of Indiana: Butler Univ. Bot. St., v. 11, p. 5–49.
GROVES, J., & BULLOCK-WEBSTER, G. R., 1920, British Charophyta. I. London.
——, 1924, *Ibid.*, II.
IMAHORI, K., 1954, Ecology, phytogeography, and taxonomy of the Japanese Charophyta: Kanazawa University, Kanazawa, Japan, 235 p., 41 pls.
MIGULA, W., 1890–1897, Die Characeen. *In* L. RABENHORST, Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz, v. 5, p. 1–765, 149 figs.
——, 1904, Characeae Rossicae: Act. Hort. Petrop., v. 23, p. 535–9.
——, 1930, Ueber einige japanischen Characeen: Hedwigia, v. 70, p. 211–5, 1 fig.
ROBINSON, C. B., 1906, The Chareae of North America: New York Bot. Gard. Bull., v. 4, p. 244–308.
WOOD, R. D., 1948, A review of the genus Nitella (Characeae) of North America: Farlowia, v. 3, p. 331–398.
——, 1952, The Characeae, 1951: Bot. Rev., v. 18, p. 317–353.
——, 1957, Hand-sorted punched cards in taxonomic research: Brittonia, v. 9, p. 65–69.
ZANEVELD, J. S., 1940, The Charophyta of Malaysia and adjacent countries: Blumea, v. 4, p. 1–224, 20 figs.

MANUSCRIPT RECEIVED JUNE 24, 1957.

CORRECTIONS

CORRECTION IN SPELLING OF *CAMAROCARCINUS ARNESONI* HOLLAND AND CVANCARA, PALEOCENE CRAB FROM NORTH DAKOTA[1]

F. D. HOLLAND, JR., AND ALAN M. CVANCARA
University of North Dakota, Grand Forks, and Ross, North Dakota

This is to call attention to an invalid original spelling (Hemming, 1953, par. 71, 1, b, i) made due to inadvertence in the heading of the species description of *Camarocarcinus arnesoni* Holland and Cvancara (1958, p. 499). Since perpetuation of this mistake would do an injustice to Mr. W. W. Arneson, discoverer of this new crab, whom it was our intention to honor, all subsequent citations of this species should be spelled as above.

[1] Published by permission of the State Geologist of North Dakota.

LITERATURE CITED

HEMMING, FRANCIS, Editor, 1953, Copenhagen decisions on zoological nomenclature: London, Internat. Trust Zool. Nomen., 135 p.
HOLLAND, F. D., JR., & CVANCARA, A. M., 1958, Crabs from the Cannonball formation (Paleocene) of North Dakota: Jour. Paleontology, v. 32, p. 495–505, pl. 74, 3 text-figs.

CORRECTIONS IN SPELLING OF TWO INVERTEBRATE FOSSILS FROM THE LOWER CARBONIFEROUS OF NEW SOUTH WALES

ALAN M. CVANCARA
Ross, North Dakota

This is to call attention to the unfortunate errors in spelling of two new species, proposed by this writer in a recent paper (Jour. Paleontology, v. 32, no. 5, p. 846–888). These species are listed below, spelled correctly, and followed by page numbers which indicate where the errors occur.

Cyathoclisia laxicolumnaris, n. sp. (p. 846, in abstract)
Plicochonetes sexifidus, n. sp. (p. 846 in abstract, p. 858 in plate explanation, and on p. 868, where originally proposed)

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 195–198, JANUARY 1959

PALEONTOLOGICAL NOTES

GENERIC AND SUBGENERIC HOMONYMS OF CONODONTS

ROBERT O. FAY
University of Oklahoma, Norman

A key for identification of genera and subgenera of conodonts has been prepared and will be printed in July 1958. In order that all taxa should have a valid name in the key it is necessary to eliminate homonyms. A systematic survey through Neave's Nomenclator Zoologicus was made in order to determine existence of homonyms. The following short list is all of the homonymous names of conodont genera or subgenera that the author was able to find at the time of writing.

Cladognathus Rexroad, 1957, is a junior homonym of *Cladognathus* Burmeister, 1847, Coleoptera. Rexroad, 1958, proposed *Kladognathus* as the new name for *Cladognathus* Rexroad, 1957.

Ctenognathus Pander, 1856, p. 32 is preoccupied by *Ctenognathus* Fairmaire, 1843, Coleoptera. *Ctenognathodus* is here proposed as the new name for *Ctenognathus* Pander, 1856.

Lepodus Branson & Mehl, 1933, is preoccupied by *Lepodus* Rafinesque, 1810, Pisces. *Lepognathodus* Mehl is here proposed as the new name for *Lepodus* Branson & Mehl (personal communication from M. G. Mehl, April 21, 1958).

Oligodus Cooper, 1939, is preoccupied by *Oligodus* Rafinesque, 1815, Coelenterata. The latter name is considered a *nomen nudum* and therefore *Oligodus* Cooper remains valid.

Prionognathus Pander, 1856, p. 34 is preoccupied by *Prionognathus* Ferté-Sénèctere, 1851, Coleoptera. *Prionognathodus* is here proposed as the new name to replace *Prionognathus* Pander.

Valentia Smith, 1907, is preoccupied by *Valentia* Stål, 1865, Hemiptera. Maurice Cossmann, 1909, proposed the new name *Scotlandia* to replace, *Valentia* Smith, but this new name has evidently been overlooked by subsequent workers.

As a result of the establishment of a new name for *Ctenognathus*, the following arrangement of subgenera is suggested.

Ctenognathodus (*Ctenognathodus*) is here proposed for all ctenognathodids that have a small subcentral escutcheon. This action excludes *Mehlina* from the subgenus. The type species is *Ctenognathus murchisoni* Pander, 1856, p. 32, pl. 4, fig. 17; pl. 6, figs. 18ab.

Ctenognathodus (*Mehlina*) is here considered the subgenus of all ctenognathodids that have no escutcheon. The type species is *Mehlina irregularis* Youngquist, 1945, p. 363, 365, pl. 56, fig. 2.

Ctenognathodus (*Pandorinellina*) Müller & Müller, 1957, was proposed to include all ctenognathodids that have a broad escutcheon. The type species is *Pandorina insita* Stauffer, 1940, p. 428–429, pl. 59, figs. 23,25. (The name *Ctenognathus* was used by Müller & Müller.)

Concerning the above three subgenera, the name *Spathognathodus* Branson & Mehl, 1941, is here considered an invalid junior subjective synonym of *Ctenognathodus* (*Ctenognathodus*). If one will observe the magnification given for the type species of *Prionognathodus* it is readily seen that it is at least 3 times the size of the largest ctenognathodid and probably is a jaw or ramus with conodonts on top, or it may not be a conodont but some type of chordate remain. For these reasons, it is probably best to exclude this genus from the ctenognathodids and reserve it for simple lamellar conodonts set in a ramus, pending further study.

REFERENCES CITED

BRANSON, E. B., & MEHL, M. G., 1933, Conodonts from the Harding sandstone of Colorado: Mo. Univ. Studies, v. 8, no. 1, p. 37.

——, 1941, New and little known Carboniferous conodont genera: Jour. Paleontology, v. 15, no. 2, p. 98.

BURMEISTER, H. C. C., 1847, Handbuch der Entomologie, v. 5, p. 364, Jena.

COOPER, C. L., 1939, Conodonts from a Bushberg-Hannibal horizon in Oklahoma: Jour. Paleontology, v. 13, no. 4, p. 398.

COSSMAN, MAURICE, 1909, Rectifications de Nomenclature: Revue critique Paléozoologie, v. 13, p. 68, Paris.

FAIRMAIRE, LÉON, 1843, Trois nouvelles espèces d'Insectes de l'Océanie: Société entomologique de France, Annales, ser. 2, v. 1, p. 13.

FERTÉ-SÉNÈCTERE, M. F. DE LA, 1851, Révision de la tribu des patellimanes Dejean, Coléoptères pentamères de la famille des Carabiques: Ibid., ser. 2, v. 9, p. 290.

MÜLLER, K. J., & MÜLLER, E. M., 1957, Early Upper Devonian (Independence) conodonts from Iowa, part I: Jour. Paleontology, v. 31, no. 6, p. 1082–1083.

NEAVE, S. A., 1939–1950, Nomenclator Zoologicus; A list of the names of genera and subgenera in Zoology from the tenth edition of Linnaeus

1758 to the end of 1935 (with supplements in each volume): Zoological Society of London, v. 1, A–C, 1939; v. 2, D–L, 1939; v. 3, M-P, 1940; v. 4, Q–Z, 1940; v. 5, A–Z for the period 1936–1945, published in 1950. Volume 5 is the first of a series of volumes intended to be published every 10 years.

PANDER, C. H., 1856, Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements: K. Akad. Wiss. St. Petersburg, p. 1–91, pls. 1–9.

RAFINESQUE, C. S. S., 1810, Caratteri di alcuni nuovi generi e nuove specie di animalie e plante della Sicilia, p. 53, Palermo.

——, 1815, Analyse de la Nature, ou tableau de l'univers et des corps organises, p. 53, Palermo.

REXROAD, C. B., 1957, Conodonts from the Chester series in the type area of southwestern Illinois: Ill. State Geol. Survey, Rept. Inv., No. 199, p. 28.

——, 1958, Conodonts from the Glen Dean formation (Chester) of the Illinois Basin: Ibid., No. 209, p. 19.

SMITH, JOHN, 1907, On the occurrence of conodonts in the Arenig-Llandeilo formations of the Southern Uplands of Scotland: Natural History Society of Glasgow, Trans., new ser., v. 7, p. 251.

STÅL, CARL, 1865, Hemiptera Africana, descript., v. 3, p. 144. Norstedt & Sons, Holmiae, Sweden.

STAUFFER, C. R., 1940, Conodonts from the Devonian and associated clays of Minnesota: Jour. Paleontology, v. 14, no. 5, p. 428–429.

YOUNGQUIST, W. L., 1945, Upper Devonian conodonts from the Independence shale (?) of Iowa: Ibid., v. 19, no. 4, p. 363,365.

A STATISTICAL STUDY OF THE MIOCENE BALANIDS FROM HUNGARY

G. KOLOSVÁRY
Syst. Zool. Institution of the University, Szeged, Hungary

The first description of a fossil balanid from Hungary was published by A. Koch in 1877 as *Balanus holgeri* Geinitz from the Miocene near Szentendre and Visegrad. Other balanids have been mentioned as follows:

1906	Gy. Halaváts:	*Balanus* sp.—Budapest.
1915	I. Vitális:	*Balanus pictus* Münster—Mt. Cserhát.
		"*Balanus holgeri* Geinitz"—Mt. Cserhát.
1925	L. Strausz:	*Balanus tintinnabulum* Linné—Fót.
1925	E. Noszky, Sr.:	"*Balanus holgeri* Münster"—Mt. Mátra.
		Balanus pictus Münster—Mt. Mátra.
		Balanus crenatus Bruguiére—Érd.
1926	E. Noszky, Sr.:	"*Pyrgoma multicostatum*" Seguenza—Mt. Mátra.
		"*Pyrgoma multicostatum*" Seguenza—Mt. Lajta.
1949	F. Horusitzky:	*Acasta schafferi* de Aless—Mt. Ceglédbercel.

In 1941 G. Kolosváry, Sr., published new data on tertiary balanids from Hungary. The collectors were: G. Stein, E. Boros, F. Legányi, E. Noszky, Sr. and Jr., Gy. Hegedüs, A. Gebhardt, H. Vereb, R. Streda, G. Kolosváry, Jr., H. Meznerics, Gy. Kókay, and S. Nagy. (See Kolosváry, 1952 and 1955.)

The material is in the Hungarian National Museum, Department of Geology-Paleontology, and in the Museum of the Central State Geological Institution at Budapest. Before 1941 only 6 Miocene fossil species were known from the Hungarian Tertiary beds; more recently 21 species are recognized.

"*Balanus holgeri*" of Geinitz and Münster is a synonym of *Balanus concavus* Bronn and "*Pyrogoma multicostatum*" Seguenza is a synonym of *Creusia rangi* Desmoulins.

The living species are excellent for our statistical study! The geographically "*ubique frequens*" species are all living species. They are attached to both organic and inorganic substrata. *Balanus concavus* Bronn has 13 synoekotic animals, and *Balanus crenatus* Bruguiére has 11 synoekotic animals. The dominant and subdominant species are all living balanids. Species with 2 to 6 subspecies are also living cirripeds.

Conservative species.—Fossil balanids with a persistent character. They are rare, without subspecies, without synoekosis and with

Geographical distribution of the fossil species

Mt. Baranya: *Balanus vadászi* Kolosváry
Mt. Mecsek: *Balanus trigonus* Darwin*
Balanus ajax Darwin (only in Tortonian beds)
Creusia spinulosa Leach
Mt. Lajta: *Balanus pictus* Münster } (only in Tortonian beds)
Creusia rangi Desmoulins }
Mt. Bakony: *Balanus vadászi* Kolosváry
Balanus amphitrite Darwin
Balanus unguiformis Darwin
Mt. Budafok: *Balanus hungaricus* Kolosváry
Balanus amphitrite Darwin
Balanus improvisus Darwin
Mt. Ceglédbercel: *Balanus laevis* Darwin
Balanus vadászi Kolosváry
Balanus amphitrite Darwin
Acasta schafferi de Alessandri (only in lower Miocene beds)
Mt. Börzsöny: *Balanus amphitrite* Darwin
Balanus pictus Münster
Balanus hontense Kolosváry
Balanus pannonicus Kolosváry
Mt. Mátra: *Balanus pictus* Münster
Creusia rangi Desmoulins } (only in Tortonian beds)
Creusia spinulosa Leach }
Mt. Bükk: *Balanus hungaricus* Kolosváry
Balanus legányii Kolosváry
Balanus vadászi Kolosváry
Balanus amphitrite Darwin
Balanus nubilus Darwin
Balanus imporvisus Darwin
Balanus borsodensis Kolosváry
Ubique frequens: *Balanus tintinnabulum* Linné
Balanus concavus Bronn
Balanus crenatus Bruguiére

Species attached to inorganic substrata

Limestone and andesite:
Balanus tintinnabulum Linné
Balanus concavus Bronn
Balanus pictus Münster
Balanus crenatus Bruguiére
Limestone, andesite, and calcite:
Balanus concavus Bronn

Species attached to organic substrata

Number of the species of the synoekotic animals

1	2	3	4	5	6	7	8	9	10	11	12	13
Creusia rangi and *C. spinulosa*	*Balanus imporvisus* and *B. unguiformis*	*Balanus hungaricus*	*Balanus tintinnabulum*		*Balanus amphitrite*					*Balanus pictus* and *B. crenatus*		*Balanus concavus*

* A living species.

DOMINANCY AND RARITY OF THE FOSSIL BALANIDS

Dominant species:	*Balanus concavus* Bronn*
	Balanus crenatus Bruguiére*
Subdominant:	*Balanus amphitrite* Darwin*
	Balanus tintinnabulum Linné*
Influent:	*Balanus hungaricus* Kolosváry
	Balanus improvisus Darwin*
	Balanus unguiformis Darwin
	Balanus pictus Münster
	Balanus vadászi Kolosváry
Subinfluent:	*Creusia rangi* Desmoulins and *C. spinulosa* Leach (only in Tortonian beds)
	Balanus trigonus Darwin*
	Balanus laevis Darwin*
	Acasta schafferi de Alessandri
	Balanus nubilus Darwin
	Balanus pannonicus Kolosváry
	Balanus legányii Kolosváry
	Balanus ajax Darwin*
	Balanus borsodensis Kolosváry

VARIABILITY OR POLYMORPHISM OF THE FOSSIL BALANIDS

Without subspecies:	*Balanus hungaricus* Kolosváry
	Balanus vadászi Kolosváry
	Balanus ajax Darwin*
	Balanus trigonus Darwin (recently found to be extremely variable)*
	Balanus pictus Münster
	Balanus nubilus Darwin*
	Balanus crenatus Bruguiére (recently found to be extremely variable)*
	Balanus pannonicus Kolosváry
	Balanus hontense Kolosváry
	Balanus unguiformis Darwin
	Balanus borsodensis Kolosváry
	Balanus laevis Darwin*
	Balanus imporvisus Darwin*
	Acasta schafferi de Alessandri
	Creusia rangi Desmoulins
With 2 fossil subspecies:	*Balanus concavus* Bronn*
	Creusia spinulosa Leach
With 4 fossil subspecies:	*Balanus tintinnabulum* Linné
With 6 fossil subspecies:	*Balanus amphitrite* Darwin*

* A living species.

a short life range.

Modified species.—The influent species, still living, with synoekotic animals, but without subspecies. Geographic range is greater than that of the conservative species and the variability greater.

Progressive-regressive species.—With subspecies still living, their distribution is cosmopolitan (see Kolosváry, 1958). Progressive forms are the living subspecies. Regressive forms are the fossil subspecies.

LITERATURE CITED

KOLOSVÁRY, GABOR, 1952, A stratigraphical study on some tertiary balanids: Ann., Hist.-Nat. Mus. Natl. Hungary, v. 2, p. 233–37.

——, 1955, Über stratigraphischer Rolle den fossilen Balaniden: Acte Biol. Szeged, v. 1, p. 183–189, figs. 1–6.

——, 1958, Systeme des phènomenes vitaux: Bull. Soc. Linnéenne de Lyon, v. 27, no. 1, p. 19–23.

MANUSCRIPT RECEIVED JULY 24, 1958

JOURNAL OF PALEONTOLOGY, V. 33, NO. 1, P. 199–201, JANUARY 1959

NOTICES

FOSSILS IN THE PUBLIC DOMAIN

Because of current interest in the problem of regulations concerning fossils in the public domain, the current rules and regulations are offered below.

UNIFORM RULES AND REGULATIONS

PRESCRIBED BY THE SECRETARIES OF THE INTERIOR, AGRICULTURE, AND WAR TO CARRY OUT THE PROVISIONS OF THE "ACT FOR THE PRESERVATION OF AMERICAN ANTIQUITIES," APPROVED JUNE 8, 1906 (34 STAT. L., 225)

1. Jurisdiction over ruins, archeological sites, historic and prehistoric monuments and structures, objects of antiquity, historic landmarks, and other objects of historic or scientific interest, shall be exercised under the act by the respective Departments as follows:

By the Secretary of Agriculture over lands within the exterior limits of forest reserves, by the Secretary of War over lands within the exterior limits of military reservations, by the Secretary of the Interior over all other lands owned or controlled by the Government of the United States, provided the Secretaries of War and Agriculture may by agreement cooperate with the Secretary of the Interior in the supervision of such monuments and objects covered by the act of June 8, 1906, as may be located on lands near or adjacent to forest reserves and military reservations, respectively.

2. No permit for the removal of any ancient monument or structure which can be permanently preserved under the control of the United States *in situ*, and remain an object of interest, shall be granted.

3. Permits for the examination of ruins, the excavation of archeological sites, and the gathering of objects of antiquity will be granted, by the respective Secretaries having jurisdiction, to reputable museums, universities, colleges, or other recognized scientific or educational institutions, or to their duly authorized agents.

4. No exclusive permits shall be granted for a larger area than the applicant can reasonably be expected to explore fully and systematically within the time limit named in the permit.

5. Each application for a permit should be filed with the Secretary having jurisdiction, and must be accompanied by a definite outline of the proposed work, indicating the name of the institution making the request, the date proposed for beginning the field work, the length of time proposed to be devoted to it, and the person who will have immediate charge of the work. The application must also contain an exact statement of the character of the work, whether examination, excavation, or gathering, and the public museum in which the collections made under the permit are to be permanently preserved. The application must be accompanied by a sketch plan or description of the particular site or area to be examined, excavated, or searched, so definite that it can be located on the map with reasonable accuracy.

6. No permit will be granted for a period of more than three years, but if the work has been diligently prosecuted under the permit, the time may be extended for proper cause upon application.

7. Failure to begin work under a permit within six months after it is granted, or failure to diligently prosecute such work after it has been begun, shall make the permit void without any order or proceeding by the Secretary having jurisdiction.

8. Applications for permits shall be referred to the Smithsonian Institution for recommendation.

9. Every permit shall be in writing and copies shall be transmitted to the Smithsonian Institution and the field officer in charge of the land involved. The permittee will be furnished with a copy of these rules and regulations.

10. At the close of each season's field work the permittee shall report in duplicate to the Smithsonian Institution, in such form as its secretary may prescribe, and shall prepare in duplicate a catalogue of the collections and of the photographs made during the season, indicating therein such material, if any, as may be available for exchange.

11. Institutions and persons receiving permits for excavation shall, after the completion of the work, restore the lands upon which they have worked to their customary condition, to the satisfaction of the field officer in charge.

12. All permits shall be terminable at the discretion of the Secretary having jurisdiction.

13. The field officer in charge of land owned or controlled by the Government of the United States shall, from time to time, inquire and report as to the existence, on or near such lands, of ruins and archeological sites, historic or prehistoric ruins or monuments, objects of antiquity, historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest.

14. The field officer in charge may at all times examine the permit of any person or institution claiming privileges granted in accordance with the act and these rules and regulations, and may fully examine all work done under such permit.

15. All persons duly authorized by the Secretaries of Agriculture, War, and Interior may apprehend or cause to be arrested, as provided in the act of February 6, 1905 (33 Stat. L., 700), any person or persons who appropriate, excavate, injure, or destroy any historic or prehistoric ruin or monument, or any object of antiquity on lands under the supervision of the Secretaries of Agriculture, War, and Interior, respectively.

16. Any object of antiquity taken, or collection made, on lands owned or controlled by the United States, without a permit, as prescribed by the act and these rules and regulations, or there taken or made, contrary to the terms of the permit, or contrary to the act and these rules and regulations, may be seized wherever found and at any time, by the proper field officer or by any person duly authorized by the Secretary having jurisdiction, and disposed of as the Secretary shall determine, by deposit in the proper national depository or otherwise.

17. Every collection made under the authority of the act and of these rules and regulations shall be preserved in the public museum designated in the permit and shall be accessible to the public. No such collection shall be removed from such public museum without the written authority of the Secretary of the Smithsonian Institution, and then only to another public museum, where it shall be accessible to the public; and when any public museum, which is a depository of any collection made under the provisions of the act and these rules and regulations, shall cease to exist, every such collection in such public museum shall thereupon revert to the national collections and be placed in the proper national depository.

WASHINGTON, D. C., *December 28, 1906*

The foregoing rules and regulations are hereby approved in triplicate and, under authority conferred by law on the Secretaries of the Interior, Agriculture, and War, are hereby made and established, to take effect immediately.

E. A. HITCHCOCK
Secretary of the Interior
JAMES WILSON
Secretary of Agriculture
WM. H. TAFT
Secretary of War

PALEONTOLOGY IN GREAT BRITAIN

The first organization in Great Britain to be founded exclusively for paleontological purposes was the Palaeontographical Society, established in 1847. From the Society has sprung a long line of sumptuously illustrated monographs. Some idea of the range and scope of these can be seen by comparing early issues, like S. V. Wood's "Crag Mollusca" (1848–1861), Owen and Bell's "Fossil Reptilia of the London Clay" (1849–1861), and Charles Darwin's two volumes on British fossil barnacles (1851–1854), with recent volumes containing the concluding parts of such works as Arkell's "Bathonian Ammonites" and Wright's "Carboniferous Crinoidea." The Society has, during its 111 years of life, laid the foundations of much of the careful paleontological work that has been a characteristic of British stratigraphy, and its monographs have become standards

of reference the world over. It is still actively engaged in its objects, and each year sees the issue of a new set of instalments of monographs in the course of publication; among those recently initiated are volumes on sponges, brachiopods, ammonites and trilobites. The Society is eager to extend its membership outside Britain. No formalities exist. Anyone sending a subscription to the Treasurer automatically becomes a member, and receives the year's issue of publications.

Perhaps the success of the Palaeontographical Society has been due in no small measure to its somewhat rigid constitution, which directs its objects to "figuring and describing British fossils." Despite this, however, there have been some disadvantages, and British paleontologists have felt the need of a society with an active programme of meetings, with discussions and demonstrations of current problems, and a journal which would publish articles of smaller scope than monographs. The growing importance of correlation on a world-wide scale has also emphasized the need for a publication policy unrestricted by territorial limitations. A new association was therefore established last year, "The Palaeontological Association," whose objectives supplement, rather than compete with, those of the Palaeontographical Society. The first three numbers of the new periodical (entitled just "Palaeontology") have now appeared, and in style and format differ a little from any other journal in the field. The range of subject matter is as wide as our science, and includes vertebrates, invertebrates, microfossils and plants; and the slant may be stratigraphical, biological, evolutionary or morphological, providing it deals with fossils. This young society, like its older associate, welcomes oversea members, and again has no formalities. A subscription secures membership.

The subscription to both societies is the same ($6.20 each, including mailing and conversion charges; no need for mail transfers; dollar checks work quite well); it should be sent to the respective treasurers; for the Palaeontographical Society, Dr. W. H. C. Ramsbottom, Geological Survey, Exhibition Road, London, S.W.7; for the Palaeontological Association, Dr. W. S. McKerrow, Department of Geology, University Museum, Oxford.

P. C. SYLVESTER-BRADLEY

SOCIETY RECORDS AND ACTIVITIES

THE PALEONTOLOGICAL SOCIETY

PROCEEDINGS OF THE FIFTIETH ANNUAL MEETING HELD AT ST. LOUIS, MO.

NOVEMBER, 6–8, 1958

BY H. B. WHITTINGTON, *Secretary*

BUSINESS MEETING

The Annual Business Meeting of the Society was called to order at 10:30 A.M. on Saturday, November the 8th, with Vice President Kenneth E. Caster in the chair. About 40 persons were in attendance.

The Officers gave their respective reports, and comment was made on some of the actions of the Council; these reports and actions are given below. The Auditors reported and the verification by Council of the annual ballot for Officers was announced. Those elected to serve from the time of the fiftieth Annual Meeting until the next in November 1959 are:

President—FRANK M. SWARTZ, University Park, Penn.
Vice-President—W. R. EVITT, Tulsa, Okla.
Editor—E. C. STUMM, Ann Arbor, Mich.
Treasurer—C. C. ALBRITTON, JR., Dallas, Texas
Secretary—H. B. WHITTINGTON, Cambridge, Mass.

The incoming President, Frank M. Swartz, then assumed the chairmanship of the Meeting and announced that in accordance with the Constitution the Council had served as a Nominating Committee and duly considered suggestions made by the membership. Nominations which will appear on the ballot in the fall of 1959 are:

For *President*—KENNETH E. CASTER, Cincinnati, Ohio
For *Vice President*—JOHN W. WELLS, Ithaca, N. Y.
For *Editor*—R. V. KESLING, Ann Arbor, Mich.
For *Treasurer*—C. C. ALBRITTON, JR., Dallas, Texas
For *Secretary*—H. B. WHITTINGTON, Cambridge, Mass.

President Swartz commented on Council actions to be taken during the coming year, which are also referred to below. Under New Business a motion was carried directing the Secretary to write to the International Commission on Zoological Nomenclature saying that the Paleontological Society was in favor of full legal status being given under the new Code to the work of animals (tracks, trails, burrows, etc). It was also moved that the Society would give all possible support to Dr. Maxim K. Elias in his efforts to secure the translation of articles in Russian on Paleontology.

Dr. E. L. Yochelson commented briefly on the probable nature of the new Code of Zoological Nomenclature and the hope that it will be published within the next year.

SCIENTIFIC SESSIONS

A three hour session was held on the morning of Friday, November 7, and a two hour session on the Saturday morning, November 8. A luncheon was held at noon on Saturday, November 8, in celebration of the Society's Jubilee, and greetings from sister Societies in North and South America, Europe, and Australia were received. In the afternoon a three hour symposium on "Fifty Years of American Paleontology" was held, more than 200 being in attendance throughout. The Paleontological Society also sponsored sessions on Sedimentation and Stratigraphy. The detailed programs of the Scientific Sessions, with abstracts, will be published in the Bulletin of the Geological Society of America for December, 1958.

REPORT OF THE COUNCIL

The Council met from 3–5:00 P.M. and 8-midnight on Wednesday, November the 8th. Apologies were received from H. B. Stenzel and A. Scott Warthin. F. M. Swartz and W. R. Evitt were present as members of

the Council elect, R. L. Langenheim and H. H. Wheeler represented the Pacific Coast section, and M. L. Thompson represented the SEPM. Reports of Officers and Representatives on Committees were read and accepted and appear below.

After discussion of the Editor's report the Council recommended that the Editor, for a test period of one year, adopt the three hundred screen half tone reproduction for plates in order to see what the quality of reproduction is and what the cost saving may be. It was the concensus of Council that the Committee on the preparation of a Catalogue of Devonian Fossils had carried its work as far as practicable. No new cards for the catalogue are in preparation at present and it is suggested that the Committee be dissolved. The Jubilee Committee met in March 1958 and the result of its deliberations was the Symposium held on Saturday afternoon. It was at this Committee's suggestion that a luncheon was arranged and it is hoped that this will become an annual event. A hearty vote of thanks to the Jubilee Committee was passed. Council recommended that no additions to the list of Correspondents be made.

At the invitation of the Geological Society of America both old and new Councils of the P.S. met with the G.S.A. Council to discuss common problems. Discussions centered largely around methods and costs of publication. P.S. receives funds from G.S.A. equal to about one third of the annual printing bill. Any change in the amount of such funds granted by G.S.A. would necessitate considerable change in our publication program. It is as a result of these discussions that P.S. Council feels it advisable to explore, through a Committee, the question of our Society's finances.

In its evening meeting, under the Chairmanship of the new President, F. M. Swartz, Council voted that the Society's books should be closed on July the 31st of 1959. The President agreed to appoint a Committee to consider the long range problems of finance of the Society, in particular that of becoming independent in regard to funds for publication. It was resolved that the President be asked to appoint a Committee to consider the Committee structure of the Paleontological Society, and in particular the mode of election of officers. Council approved the making of a merit award in paleontology, and requested the President to appoint a Committee to consider the details of such an award. The Pacific Coast branch was invited by Council to examine the instructions to authors as recently published in the *Journal* and to suggest any emendations or additions they consider fit. The Council voted that a grant of $100.00 be made to the A.G.I. this year and $50.00 to the Zoological Record fund of the Zoological Society of London.

The hope was expressed that it might be possible to publish the papers offered in the symposium on Saturday afternoon and to make reprints of these articles available for sale separately. The International Paleontological Union is compiling a world list of Paleontologists with their specialties. K. E. Caster is in charge of supplying the information for North America. It was agreed that the Paleontological Society would pay postage on circulars sent out in this connection by Dr. Caster to members of the Society.

A hearty vote of thanks to the local committee is to be conveyed by the Secretary.

REPORT OF THE SECRETARY

To the Council of the Paleontological Society:

I have the honor to submit the following report for the year ending 8 November 1958:

The proposed change to the By-laws of the Society (see notice in the *Journal*, vol. 32, p. 646) were passed by an overwhelming majority, and it should now be not more than four weeks between receipt of a Nomination for Membership and notification of election.

The joint program committee which met in New York in August was attended by F. C. Whitmore, Jr. and the Secretary as a conferee.

Necrology.—During the year the Society lost one correspondent and seven members by death:

W. J. Arkell (Correspondent)
R. A. Bramkamp
Charles E. Decker
Max W. deLaubenfels
Raymond R. Hibbard
Frank E. Peabody
John B. Reeside
Burnett Smith (Original Fellow)
Charles E. Weaver

Membership.—New proposals for membership have come in steadily throughout the year; the names of those elected having been listed in the *Journal*, vol. 32, p. 645, 1037. The net gain in members of our Society is 39 (as compared with 43 last year).

Respectfully submitted,
H. B. WHITTINGTON
Secretary

3 November 1958

REPORT OF THE TREASURER

To the Council of the Paleontological Society:

I have the honor to present the following report on the finances of the Society, covering the year from November 1, 1957, to October 31, 1958.

Total receipts amounted to about a thousand dollars more than for the previous year, but our expenditures increased by nearly $3,400. Accordingly, the cash reserve has decreased to about $5,000, as compared with more than $11,000 in 1955.

RECEIPTS

I. Balance brought forward from November 1, 1957			$ 7,430.28
II. Membership dues received:			
A. Dues from members receiving the *Journal of Paleontology* through the Paleontological Society:			
1959 dues: 394 at $10.00	$3,940.00		
1 at 10.25	10.25		
1 at 10.40	10.40		
1 partial payment at $8.00	8.00		
1 partial payment at $5.00	5.00		
		$3,973.65	
1958 dues: 305 at $10.00	$3,050.00		
1 at 10.50	10.50		
1 at 12.50	12.50		
		3,073.00	
1957 dues: 6 at $ 8.00	$ 48.00		
1 at 10.00	10.00		
		58.00	
1956 dues: 2 at $8.00	16.00	16.00	
1955 dues: 1 at $6.00	6.00	6.00	
Total dues from members receiving *Journal* through Paleontological Society		$7,126.65	
B. Dues from members not receiving *Journal of Paleontology* through the Paleontological Society:			
1959 dues: 77 at $2.00	$ 154.00		
1 at 5.00	5.00		
		$ 159.00	
1958 dues: 45 at $2.00	90.00	90.00	
1957 dues: 1 at $2.00	2.00	2.00	
1960 dues: 1 at $2.00	2.00	2.00	
Total dues from members not receiving *Journal* through Paleontological Society		253.00	
Total, membership dues received	$7,379.65		
Less service charge by bank (foreign exchange) 1 at $0.50	.50		
Total, membership dues accrued			$ 7,379.15
III. Contributions in support of the *Journal of Paleontology*, received from the Penrose Bequest of the Geological Society of America:			
Special allocation for long manuscript, September 1957 issue	$ 236.25		
January 1958 issue	4,932.18		
Special allocation for long manuscript, May 1958 issue	1,187.13		
Total, contributions in support of the *Journal of Paleontology*, received from the Penrose Bequest of the Geological Society of America		$6,355.56	

IV. Special contributions received in support of the *Journal of Paleontology:*			
Cornell University, in behalf of paper of John W. Wells	$ 24.45		
In behalf of C. E. Decker paper,			
Mrs. C. E. Decker	100.00		
J. A. Hord	94.50		
University of Oklahoma	100.00		
C. W. Tomlinson, in behalf of paper of M. K. Elias.	192.20		
Total, special contributions received in support of the *Journal of Paleontology*		$ 511.15	
V. Apportioned income received from subscriptions and sales, *Journal of Paleontology:*			
1957 remittance from Society of Economic Paleontologists and Mineralogists	$4,646.05		
		$4,646.05	
VI. Income received from sale of reprint of Symposium on Explosive Evolution, 5 at $2.00	$ 10.00	10.00	
Total receipts			$26,332.19

DISBURSEMENTS

(check numbers given in parentheses)

I. Publication expense, *Journal of Paleontology:*			
Reprints of Editors' Advice to Authors (366)	$ 33.84	$ 33.84	
January 1958 issue			
Plates and authors' reprints (367)	1,753.91		
Printing (370)	5,024.23		
		6,778.14	
Half cost, annual index for 1957 (371)	60.34	60.34	
May 1958 issue			
Plates and authors' reprints (373)	2,132.85		
Printing (374)	4,895.58		
		7,028.43	
September 1958 issue			
Plates and authors' reprints (376)	$1,647.25		
Printing (383)	4,795.16		
		6,442.41	
Total, disbursements for publication expense of *Journal of Paleontology*			$20,343.16
II. Publication expense, other than for publication of *Journal of Paleontology:*			
Correspondents of the Paleontological Society, 11 members at $7.70 per member (372)	$ 84.70		84.70
III. Special supporting contributions			
Zoological Society of London (362)	50.00		
American Geological Institute (363)	100.00		
Total, special supporting contributions			150.00
IV. Expenses of Offices of the Society			
A. Secretary's Office			
Travel subsidy, 1957 meetings (360)	$ 27.60		
Postage (364)	36.50		
Postage (382)	6.13		
Envelopes and addressing of same for annual balloting (375)	43.33		
Postage and secretarial help (378)	28.00		
Printing of ballots and envelopes (379)	49.69		
		$ 191.25	
B. Editor's Office			
Secretarial expense, postage, etc. (380)	$ 200.00		
		200.00	

C. Treasurer's Office		
Travel subsidy, 1957 meetings (361)	$ 64.99	
Security Bond (365)	5.00	
Secretarial help (368)	102.00	
Secretarial help (381)	65.50	
Postage (369)	15.82	
Postage (377)	47.69	
		301.00
Total disbursements for expenses of Offices of Society		$ 692.25
Total, disbursements for year ending October 31, 1958		$21,270.11
Cash-on-hand, October 31, 1958 in Hillcrest State Bank, University Park, Dallas, Texas		5,062.08
Total, disbursements for year ending October 31, 1959, plus cash-on-hand, October 31, 1958		$26,332.19

AUDITOR'S REPORT

To the Council of the Paleontological Society:

We, the undersigned, acting as auditors appointed by Vice President Kenneth E. Caster, have this day examined the books and records of the Treasurer's Office covering activities of the Society during the past year, and have found these records and books in good order and correct to the best of our knowledge.

Respectfully
R. L. LANGENHEIM
ELLIS L. YOCHELSON

EDITOR'S REPORT FOR 1958

The Paleontological Society in its three issues of the *Journal of Paleontology* for 1958 published 31 articles on invertebrate paleontology, 13 on micropaleontology, 8 on vertebrate paleontology, and 1 on paleobotany, in addition to several Paleontological Notes Nomenclatural Notes, and Reviews. The total 748 pages and 102 plates, compared with 683 pages and 72 plates last year, represents an increase of 10% in pages and 42% in plates.

The article on graptolites by Charles Decker was referred to the Paleontological Society by the Geological Society of America, which paid the entire cost of its publication. In addition, in two long articles the cost of plates was borne in part by the contributors.

As of October 13, 1958, the editors have on hand 41 manuscripts, comprising 1,478 typed pages and 77 plates. This is nearly enough for all issues of 1959. It contrasts sharply with the backlog of last year, which was only sufficient for one issue.

The topical content of the Paleontological Society's numbers of volume 32 is compared in table 1 with those of volumes 28 to 31.

REPORT OF THE DEVONIAN CATALOGUE COMMITTEE

The Committee has received no clear directive from Council or the Society membership generally, since it requested such advice a year ago. It has therefore marked time, and has committed itself to the publication of no new units during the year.

TABLE 1.—TOPICAL ANALYSIS OF CONTENTS OF THE PALEONTOLOGICAL SOCIETY'S NUMBERS OF THE JOURNAL OF PALEONTOLOGY

Year	1954	1955	1956	1957	1958
Volume	28	29	30	31	32
Pages:					
Invertebrate paleontology	355	429	418	537	452
Micropaleontology	9	49	150	51	193
Vertebrate paleontology	60	101	207	53	74
Paleobotany	11	8	19	8	11
Notices, records, misc.	17	5	18	34	18
Total pages	432	592	812	683	748
Plates	52	73	92	72	102

Four of the 13 units published are out of print, and only one of the nine units still available is represented by a stock of over 30 copies.

Publication costs were originally financed by loan from the Wagner Free Institute of Science. Sales to other than regular subscribers have allowed the accumulation of a revolving publication fund of about $2,000. Inventory of the remaining stock totals about $900.

Preparation of units requires a large amount of time, for which authors are reimbursed to the extent of one free copy and (latterly) a minuscule contribution toward their out-of-pocket expense. In view of the limited circulation of the Catalogue it may well be asked whether this is a good use of a busy specialist's time.

Respectfully submitted,
M. A. FRITZ
R. CHAMBERS, JR.
B. F. HOWELL
A. K. MILLER
A. S. WARTHIN JR., *Chrmn.*

Oct. 25, 1958

REPORT OF THE SPECIAL COMMITTEE ON CORRESPONDENTS

1. The Committee is divided on the question of continuance of the Correspondent class of membership. One member feels that it should be continued as at present; the other two feel that while the present list should be continued, no further additions should be made, with ultimate abandonment of the class.
2. Irrespective of any action Council may take with regard to Correspondents, the Committee is unanimous in recommending that efforts be made to increase our foreign membership.
3. The Committee is unanimous in its feeling that Society funds are better spent in support of A.G.I. and the Zoological Record than in support of Correspondents.
4. If Correspondents are to be continued, the Committee is agreed that the list be limited, representative of diverse branches of paleontology, and confined to old rather than mature or young paleontologists.
5. If Council decides to continue the classification and make new appointments, the Committee is agreed that this should not be done amid the pressure of business of the annual Council meeting. The Committee is therefore not submitting to Council for action at their meeting the 15 names which have been suggested to us. If Council decides to add to the present list of Correspondents, the Committee will submit these names to Council for their leisurely consideration and mail balloting.

Respectfully submitted,
K. E. CASTER
H. S. LADD
A. S. WARTHIN, JR., *Chrmn.*

Oct. 25, 1958

REPORT OF THE PALEONTOLOGICAL SOCIETY REPRESENTATIVE ON THE NATIONAL RESEARCH COUNCIL, DIVISION OF EARTH SCIENCES AND DIVISION OF BIOLOGY AND AGRICULTURE, 1958

For the first time all divisions of the National Research Council met simultaneously to discuss five common problems: (1) Education in Science; (2) International Aspects of Science; (3) Beyond the International Geophysical Year; (4) Information and Documentation in Science; and (5) Problems in the Stimulation of Interdisciplinary Research. The meeting then broke into five groups, each of which discussed one of these topics.

Subsequent reports of these study groups indicated two main trends. 1. There is an awareness of deficiences in the American education system on all levels. Nearly half of the time of each of these study groups was devoted to comment on this problem. 2. There is some east-west cooperation in scientific matters, much of it fostered by the IGY program. Unless the world political situation deteriorates, this cooperation will probably increase slowly with time.

The brief annual meeting of the Division of Earth Sciences was devoted primarily to reports of committees. An interdivisional committee on oceanography has been set up with Dr. Harrison Brown, California Institute of Technology, as chairman. This committee is broadly based and will consider among other items, problems in biol-

ogy, meteorology and chemistry of the oceans.

Another committee has been formed to consider drilling a deep hole to the Mohorovicic (Moho) discontinuity. It would require drilling to about 100,000 feet on land, or about 30,000 feet at sea. If the committee feels the project worthwhile, money will be requested for site and engineering studies. Submarine drilling at depth presents many technical problems, but it could result in a core providing a complete unbroken record of fossils going back in time for as long as they had parts suitable for preservation.

The brief annual meeting of the Division of Biology and Agriculture was devoted primarily to means of improving biological education in the United States. The Division Committee on education policies has prepared a sourcebook for high school biology teachers. Several hundred possible experiments and observations are discussed. About three pages are devoted to geologic time and to fossils as possible material for high school study.

Two publications of the division may be of interest to those members of the Paleontological Society in academic institutions: "Recommendations on undergraduate curricula in the biological sciences," National Research Council publication 578; "Concepts in biology," published as the April, 1958 issue of *Behavioral Science*. This is an edited account of a three day conference by about a dozen biologists in an attempt to determine what are the underlying principals in their field. The report will eventually be published by the National Research Council.

Respectfully submitted,
ELLIS L. YOCHELSON

PROCEEDINGS OF THE FORTY-FIFTH ANNUAL MEETING OF THE PACIFIC COAST SECTION OF THE PALEONTOLOGICAL SOCIETY, HELD AT THE UNIVERSITY OF OREGON, EUGENE, OREGON

MARCH 28, 1958

BY R. L. LANGENHEIM, JR., *Secretary*

The Forty-fifth Annual Meeting of the Pacific Coast Section of the Paleontological Society of America was held at the University of Oregon, Eugene, Oregon on Friday, March 28, 1958.

LUNCHEON AND BUSINESS MEETING

A luncheon and business meeting was held at noon Friday, March 28, 1958 at the Erb Memorial Union, University of Oregon. Twenty-one members and guests were in attendance. Chairman E. M. Baldwin presided.

Reading of the minutes of the last meeting was dispensed with upon unanimous vote of the members present.

The following slate of officers for the year 1958–59 was presented by the chairman of the nominating committee, Dr. V. J. Okulitch:

Chairman
V. S. MALLORY—University of Washington, Seattle, Washington

Vice-Chairman
J. F. LANCE—University of Arizona, Tucson, Arizona

Secretary
R. L. LANGENHEIM, JR.—University of California, Berkeley, California

Councilor
H. E. WHEELER—University of Washington, Seattle, Washington

The slate was unanimously elected by members of the Section present.

R. L. Langenheim, Jr. presented an informal report of the proceedings of Council meeting held in Atlantic City, dealing for the most part with problems arising from possible changes in publication processes for

the Journal of Paleontology. Further information and comments were offered by Dr. R. C. Moore, President of the Geological Society of America and by Dr. H. R. Aldrich, Secretary of the Geological Society of America.

BALLOTING REPORT

To the Council of the Paleontological Society:

We, the undersigned, have examined the ballots returned to the Secretary's office by October 17 in the Annual Vote of the Paleontological Society and find the following results:

1. Total number of ballots returned—361.
2. Ballots invalidated by (a) absence of name on mailing envelope, or (b) name on inner envelope—53.
3. On the 308 valid ballots the vote was as follows:

	For	*Against*	*Blank*
(a) *President*			
FRANK M. SWARTZ	306	2	
(b) *Vice President*			
WILLIAM R. EVITT	302	5	1
(c) *Secretary*			
HARRY B. WHITTINGTON	307	1	
(d) *Treasurer*			
CLAUDE C. ALBRITTON, JR.	306	1	1
(e) *Editor*			
ERWIN C. STUMM	303	3	2

4. Proposed additions and changes to the by-laws. On the 233 valid ballots the vote was as follows:

For	*Against*	*Blank*
224	9	

Respectfully submitted
CRAIG C. BLACK
ALLEN S. HUNT

It was moved by W. F. Scott that Councilor Wheeler be instructed to investigate the reasons for the constitutional provision prohibiting election of the Vice President of the Paleontological Society to the Presidency for the year succeeding his term as Vice President and that, if there appeared to be no valid reason for this provision, he introduce a motion at the next council meeting for a constitutional amendment permitting such election. The motion was seconded by V. J. Okulitch and passed unanimously.

It was moved by V. S. Mallory that Councilor Wheeler be instructed to investigate the possibility of establishing continuity in the Society's editorial policy by the appointment of a permanent Executive Editor or by preparation of a written editorial manual. The motion was seconded by J. W. Durham and passed unanimously.

The Chairman called upon Dr. R. C. Moore for a report on the current status of the Treatise on Invertebrate Paleontology.

It was moved by Dr. V. S. Mallory that the appreciation of the Section for the arrangements of the meeting and field trips by the staff of the University of Oregon be expressed by vote of the Section. The motion was seconded by J. W. Durham and passed by acclamation.

There being no further business, the meeting adjourned at 1:00 P.M.

Respectfully submitted
R. L. LANGENHEIM

PROPOSED NEW MEMBERS OF THE PALEONTOLOGICAL SOCIETY

In accordance with Article 3, Chapter 1, of the By-Laws of the Paleontological Society, the names of new members approved by the Council are as follows:

ANDERSON, MICHAEL MARCHMONT, Geology Dept., University of Mandalay, Mandalay, Burma: H. B. Whittington, B. Kummel.

BEARD, JOHN H., Geology Dept., University of Utah, Salt Lake City, Utah: Walter Sadlick, H. B. Whittington

CLARK, DAVID LEIGH, Geology Department, Southern Methodist University, Dallas 5, Texas: James E. Brooks, Claude Albritton.

CRAMER, HOWARD ROSS, Department of Geology, Emory University, Atlanta 22, Ga.: John W.

Price, Sr., L. L. Sloss, Bernhard Kummel.

DAVIS, RICHARD ALBERT, JR., 815 College St., Beloit, Wisconsin: Robert V. Kesling, Erwin C. Stumm.

HAYES, WARREN DEAN, c/o Seismograph Service Corp., Box 1590, Tulsa, Okla.: A. G. Unklesbay, Raymond E. Peck.

HEUBUSCH, CAROL A. (Miss), Buffalo Museum of Science, Humboldt Park, Buffalo, N. Y.: Max J. Kopf, Irving H. Tesmer.

JONES, JAMES IRVIN, Dept. of Geology, Science Hall, University of Wisconsin, Madison, Wis.: Roger L. Batten, L. N. Cline.

LIVINGSTON, HAROLD R., 117 S. Harris Rd., Ypsilanti, Michigan: Erwin C. Stumm, Claude W. Hibbard.

RAGAN, WENDELL J., 10 Court Street, Columbia, Mo.: A. G. Unklesbay, Raymond E. Peck.

STONE, DWAYNE DAVID, Geology Dept., University of Utah, Salt Lake City, Utah: Walter Sadlick, W. M. Furnish, Jr.

12 December 1958

Lack of reply by return mail will be taken to indicate approval.

PRICE LIST

THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

P.O. Box 979, Tulsa 1, Oklahoma

Journal of Paleontology

Vol. 1 (Bound—Paper, $6.00; Cloth, $6.50)
Vol. 2 (1928), Nos. 1,2,3,4
Vol. 4 (1930), No. 4,—Supplement
Vol. 5 (1931), Nos. 1,2,3
Vol. 7 (1933), Nos. 1,2,3,4
Vol. 8 (1934), Nos. 3,4
Vol. 9 (1935), Nos. 1,2,3,4,5,6,7,8
Vol. 10 (1936), Nos. 1,2,3,4,5,6,7,8
Vol. 11 (1937), Nos. 1,2,3,4,5,6,7,8
Vol. 12 (1938), Nos. 3,4,5,6
Vol. 13 (1939), Nos. 1,2,3,4,5,6
Vol. 14 (1940), Nos. 1,2,3,4,5,6
Vol. 15 (1941), Nos. 1,2,3,4,5,6
Vol. 16 (1942), Nos. 1,2,3,4,5,6
Vol. 17 (1943), Nos. 1,2,3,4,5,6
Vol. 18 (1944), Nos. 1,2,3,4,5,6
Vol. 19 (1945), Nos. 1,2,3,4,5,6
Vol. 21 (1947), Nos. 3,4,5,6
Vol. 22 (1948), Nos. 3,4,5,6
Vol. 24 (1950), Nos. 2,3,4,5,6
Vol. 25 (1951), Nos. 3,4,5,6
Vol. 26 (1952), Nos. 3,4,5,6
Vol. 27 (1953), Nos. 1,2,3,4,5,6
Vol. 28 (1954), Nos. 1,2,3,4,5,6
Vol. 29 (1955), Nos. 1,2,3,4,5,6
Vol. 30 (1956), Nos. 2,5,6
Vol. 31 (1957), Nos. 1,2,3,4,5,6
Vol. 32 (1958), Nos. 1,2,3,4,5,6

PRICE PER ISSUE: Non-Member, $3.00; Member, $1.75

Journal of Sedimentary Petrology

Vol. 1 (1931), No. 2
Vol. 2 (1932), Nos. 1,2,3
Vol. 3 (1933), Nos. 1,2,3
Vol. 4 (1934), No. 3
Vol. 5 (1935), Nos. 1,2
Vol. 20 (1950), Nos. 1,2,3,4
Vol. 22 (1952), Nos. 1,2,3
Vol. 23 (1953), Nos. 1,2,3,4
Vol. 24 (1954), No. 4
Vol. 25 (1955), Nos. 1,2,3,4
Vol. 26 (1956), Nos. 1,2,3,4
Vol. 27 (1957), Nos. 1,2,3,4
Vol. 28 (1958), Nos. 1,2,3,4

PRICE PER ISSUE: Non-Member, $3.00; Member, $1.50

Special Publications

	Non-Member	*Member*
No. 2—Turbidity Currents and the Transportation of Coarse Sediments to Deep Water	$2.75	$ 2.25
*No. 3—Finding Ancient Shorelines	$3.00	$ 2.50
*No. 4—Recent Marine Sediments (Reprinted with Additions)	$5.00	$ 4.00
*No. 5—Regional Aspects of Carbonate Deposition	$4.50	$ 3.50
No. 6—Index to Journal of Sedimentary Petrology	$1.50	$ 1.25

*Members of AAPG may purchase at member price.

Annual Membership Dues, including the Journal of Paleontology	$10.00
Annual Membership Dues, including the Journal of Sedimentary Petrology	$ 7.00
Annual Membership Dues, including Both Journals	$17.00
*Non-Member Subscriptions to Journal of Paleontology	$15.00
*Non-Member Subscriptions to Journal of Sedimentary Petrology	$ 9.00

*Add 40¢ for each subscription outside the United States.

Agents are allowed a 10% discount on back numbers and subscriptions.

WILEY

Offers an introduction to general paleontology, including material on plants, invertebrates and vertebrates

TIME, LIFE AND MAN

The Fossil Record

By Ruben Arthur Stirton, *Professor of Paleontology; Director, Museum of Paleontology, University of California, Berkeley.* This book provides a comprehensive treatment of paleontology, outlining methods and principles. It includes a condensed classification of plants and animals; a discussion of the sequence of life and environment; and special sections on selected subjects, such as, dinosaurs, horses, ammonites, birds, and man. The author emphasizes: identification, form and function, associations of plants and animals, evolution in the different groups of organisms, and dispersal and distribution of plants and animals through time and space.

Concentrates on sequence of life from Precambrian to the Pleistocene Era . . .

The first five chapters outline the objectives and general principles to which attention is directed throughout the book. This is followed by a history of paleontology tracing the changes in concepts and the evolution of thought on the subject. The author then presents a simplified classification of plants and animals, both living and extinct. The core of the work deals with a chronologic presentation of the sequence of life from the Precambrian to the Pleistocene Era. In many respects this section of the book is much like historical geology, but the fossil record is emphasized more than the physical events in the earth's history. The last nine chapters are based on selected subjects and stress applications of the information presented in preceding chapters.

Special features . . .

- The author discusses the methods of locating, collecting and curating specimens, as well as preparing them for study.
- Scientific and common names, in their various usages for fossils, are utilized to acquaint the student with terms he may encounter in outside or assigned readings.
- Throughout the book attention is directed to individuals who have contributed to our terminology, to our knowledge of fossils, and to the study of the sequence of life.

Send for an examination copy.

1959 559 pages Illus. College Edition $7.50

JOHN WILEY & SONS, Inc. 440 Fourth Avenue, New York 16, N.Y.

McLEAN PALEONTOLOGICAL LABORATORY

Card catalogues of fossils available by subscription, created on contract or by mutual agreement. Compilation and research facilities by contract. Training program for micropaleontologists offered.

James O. McLean, Jr., Box 716, Alexandria, Virginia, U.S.A.

MICROFOSSILS OR MACROFOSSILS

Whatever your laboratory or classroom needs may be—if it's study fossil material you require for your students or for exhibition—our incomparable stock of fossil invertebrates and bulk micromaterial is available for immediate delivery.

PALEONTOLOGICAL RESEARCH LABORATORY
221 N. MULBERRY STREET
STATESVILLE, NORTH CAROLINA

...the sand sample that can't be identified when it reaches the lab—the sample that *could* influence decisions concerning future development of an entire field—the sample that is lost forever *because of a faulty container*...

THIS handful of sand can cost you thousands of dollars!

Sand samples are important. They cost at least $2.00 each to collect and process. Yet up to 25% are dumped uncut because of illegible tags or inferior bags. Lost is the investment in handling costs. Forever lost is valuable information. Stop such losses with HUBCO PROTEXO SAND SAMPLE BAGS. We'd like to tell you the whole story behind HUBCO Protexo Bags. For more information, a sample and dealer's name *mail in the coupon.*

PROTEXO BAGS
• Strong • Soil-proof
• Geologist-designed
• Highest Quality Cambric Cloth
MAGIC SEAL TAPE
• Water-based and Mildew-proof
• Guaranteed to keep entire ordinary parcel inviolate before,

HUBCO Protexo Bags were designed with the GEOLOGIST in mind.

HUTCHINSON BAG CORPORATION Dept. JP
P. O. Box 868, Hutchinson, Kansas

Name_____
Company_____
Street_____
City_____ State_____